İSTANBUL TECHNICAL UNIVERSITY ★ INSTITUTE OF SCIENCE AND TECHNOLOGY

SUITABILITY OF ENTERPRISE RESOURCE PLANNING (ERP) SYSTEMS IN CONSTRUCTION BUSINESS

M.Sc. Thesis by

Tuğçağ Arda ÇOTUK

Department : ARCHITECTURE

Program : PROJECT AND CONSTRUCTION MANAGEMENT

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Supervisor (Chairman): Prof. Dr. Alaattin Kanoğlu

Members of the Examining Committee Assoc. Prof. Dr. Atilla Dikbaş

Assist. Prof. Dr. Almula Köksal

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

KURUMSAL KAYNAK PLANLAMA (KKP) SİSTEMLERİNİN İNŞAAT SEKTÖRÜNE UYGUNLUĞU

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LIST OF ABBREVIATIONS

A$	Australian Dollar
A/E	Architect / Engineer
AIM	Application Implementation Methodology
APS	Advanced Planning and Scheduling
BOM	Bill of Materials
CRM	Customer Relationship Management
D/R	District`s Representative
DBMS	Database Management System
EDI	Electronic Data Interchange
EFT	Electronic Fund Transfer
ERP	Enterprise Resource Planning
G/C	General Contractor
IC	Inventory Control
IDMS	Information Data Management Systems
IMS	Information Management Systems
IS	Information Systems
IT	Information Technology
JIT	Just in Time
KM	Knowledge Management

MMS	Material Management System
MRP	Material Requirements Planning
MRP II	Manufacturing Resources Planning
O	Owner
O/R	Owner`s Representative
PMS	Project Management Systems
RFI	Request for Information
RFP	Request for Proposal
ROI	Return on Investment
S/C	Subcontractor
S/V	Suppliers and Vendors
SME	Small and Medium Sized Enterprises
SMU	Single Monitory Unit
TCO	Total Cost of Ownership
US$	United States Dollar
WAN	Wide Area Network
Y2K	Year 2000

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SUMMARY

SUITABILITY OF ENTERPRISE RESOURCE PLANNING (ERP) SYSTEMS IN CONSTRUCTION BUSINESS

ERP systems are the most sophisticated and complex integrated systems available in the market, and they provide siginificant benefits in running businesses of various industries. Although ERP systems currently handle many business functions of enterprises, referring to companies, vendors, manufacturers, private and governmental organizations, there still some industry specific needs exist in accordance with the nature of the industry. Due to its fragmanted nature and complicated processes, construction business needs specific solutions to its functions working deficiently or unsatisfactorily. In this study, starting with comprehensive explanation of ERP systems and their respective phases witihin an ERP application lifetime, ERP system applications in construction industry have been investigated. Current major construction ERP products are reviewed, science based knowledge of researchers from ERP developers and field based experience of the private sector have been utilized, available conceptual models are provided, and in the light of these, construction industry specific problems have been determined, and possible solutions and sugestions are presented. This study also discusses the suitability of ERP systems in construction business, provides general fits into the construction business, and also evaluates the suitability of ERP systems to the specific parties including owners, owner's representatives, architect / engineers, manufacturers, vendors, and finally subcontractors and general contractors accordingly.

ÖZET

KURUMSAL KAYNAK PLANLAMA (KKP) SİSTEMLERİNİN İNŞAAT SEKTÖRÜNE UYGUNLUĞU

Kurumsal Kaynak Planlama (KKP) sistemleri günümüzde yazılım piyasasında mevcut olan en gelişmiş ve kapsamlı bütünleşik sistemlerdir, ve kullanıldığı takdirde birçok endüstride göze çarpan faydalar sağlamaktadır. Mevcut KKP sistmelerinin, şirketler, üreticiler, satış firmaları, özel organizasyonlar ve devlet kuruluşları dahil olmak üzere, kurumların çok sayıdaki iş fonksiyonlarına cevap verebilmelerine rağmen, belli endüstrilerde halen özel koşullardaki problemlere cevap veren çözümlere ihtiyaç vardır. İnşaat sektörü, parçalı yapısı ve karmaşık iş operasyonlarından dolayı aksayan ve tatmin edici bir seviyede çalışamayan fonksiyonlarına uygun çözümler bulunmasına ihtiyaç duymaktadır. Bu çalışmada KKP sistemleri ve KKP sistemleri uygulamaları boyunca gerçeklesen tüm süreçler kapsamlı olarak anlatılmış, ve inşaat sektöründeki KKP uygulamaları araştırılmıştır. İnşaat alanındaki belli başlı KKP ürünleri gözden geçirilmiş, KKP geliştiren araştırmacıların teorik bilgileriyle özel sektörün tecrübesiyle edinilen bilgiler bir araya getirilmiş, mevcut kuramsal modeller dile getirilmiş ve bu bilgiler ışığında, inşaat sektörünün kendine özgü yapısından kaynaklanan ve KKP sistemleri kullanımı esnasında ortaya çıkan problemler belirlenerek, bu problemlere ilişkin muhtemel çözümler ve öneriler sunulmuştur. Bu çalışma aynı zamanda KKP sistemlerinin inşaat sektörüne uygunluğunu incelemekte, genel olarak inşaat sektörüne uygunluğunun yanısıra, mal sahipleri, mal sahibi temsilcileri, mimarlık / mühendislik şirketleri, üreticiler, satış firmaları, alt yükleniciler ve ana yükleniciler dahil olmak üzere, Kurumsal Kaynak Planlama sistemlerinin inşaat sektörü katılımcılarına uygunluğunu ayrı ayrı değerlendirmektedir.

1. INTRODUCTION

During improvement period of construction business, many basic solutions have led to advanced ones. In the history of construction, basic needs made people discover crucial solutions starting from ancient shelters to today's high-technology buildings. Better solutions have been needed in order to achieve complex projects since people have been demanding for more complex and large-sized projects. New demands of construction business have originated many sub-sectional improvements among construction business' component sectors such as material manufacturing companies, structural design engineering solutions, composite material use, material technologies, building production systems, construction technologies, and construction management as well. The increase in complexity of new projects has required more capable techniques, means, and methods in order to achieve projects on time and complete successfully within the anticipated budget without sacrificing the quality. These needs forced the market and all of its companies to figure out better management solutions to keep their competitiveness. Being an enabler of integrating many resource-based activities in organizations, enterprise resource planning (ERP) systems, which are proved to provide considerable benefits in manufacturing businesses, have begun to be regarded as a solution for handling construction business.

In this research study, the major goal is to introduce the concepts related to ERP systems, and in the light of an extensive literature survey, to discuss the suitability of ERP in construction. Below sections mention the background for this research, problem determination, and statement of problem, refer to the related studies performed so far, establish the aims and objectives of the research, introducing the method of research, discuss the scope and limitations, and finally presenting a research calendar.

1.1 Background of The Research

In the current globalized business environment, companies need to maintain their competitiveness in their markets. In order to do so, they should seek for better ways to keep up the recent technologies applied to their business. There have been many computer based business solutions since 1960's such as calculation applets, process based applications, functional solutions, project-based solutions, and since 1990's, enterprise-based solutions. Companies need to identify their workflow, standardize their processes, and control all business functions and their financial aspects. They also need integrated systems to keep their business under control while growing. Computer technology has brought about many benefits in helping the construction industry to meet increasingly complex challenges, achieving a wide range of successful applications at the project level such as engineering design, project estimating, scheduling, planning and control, and integrated project management. The ERP systems are the most comprehensive and most complicated business solutions up to date that provides an integrated multifunctional, multi-site, and multinational business management tool.

The term "ERP" originally implies systems designed to plan the use of enterprise-wide resources. ERP is originated from manufacturing and production planning systems (Fitzgerald, 1992). The evolution of ERP started in 60's as custom-made information systems (IS) for inventory control (IC), which is followed by the introduction of material requirements planning (MRP) systems. In the 1980's, manufacturing resources planning (MRP II) systems evolved to incorporate the financial accounting system and the financial management system along with the manufacturing and materials management systems. By the early 1990's, continuing improvements in technology allowed MRP II to be expanded to incorporate all resource planning for the entire enterprise. Now, ERP is a key technology enabler integrating demand, supply, manufacturing, scheduling, transportation, and network optimization functions of corporations.

Dealing with the areas such as product design, information warehousing, materials planning, capacity planning, communication systems, human resources, finance, and project management, ERP has become popular in the last decade in many sectors.

1.2 Problem Statement

ERP systems typically attempt to cover all basic functions of an organization, regardless of the organization's business. Because of their wide scope of application within a business, ERP software systems are typically complex and usually impose significant changes on staff work practices. Customizing an ERP package can be very expensive and complicated, because many ERP packages are not designed to support customization, so most businesses implement the best practices embedded in the acquired ERP system. However, majority of operations in construction business are customized and unstandardized operations. Implementation of ERP in an organization necessitates a complete understanding of the needs of ERP, an accurate system selection, analysis of costs and benefits born by the implementation, a proper road map to establish the system, and correct strategies developed and applied by a strongly committed team.

Many researchers have studied the concept of ERP systems in various perspectives; system selection, implementation process, needs, benefits, and costs of implementing ERP systems have been analyzed and proper strategies and models have been proposed considering the features of the work processes and the organization as well. However, there is limited research in the area of ERP systems in construction and there is a need for a sound and deep analysis of the properties of an ERP model to be applied to construction business that will best suit the requirements of the companies and function properly. Within this context, the suitability of ERP systems will be discussed by considering the unique features of construction business that differentiates it from other industries, as well as the costs, benefits, requirements, system selection, and implementation issues in general, and possible difficulties within the life-cycle of an ERP system in construction will be investigated.

1.3 Related Studies

Since ERP is extremely wide and complicated system, it has not been practically possible to determine all problems and provide a complete resolution on system needs in construction business. Therefore, previous studies have focused on certain part of the system due to time and scope limitations.

Many researchers have studied on ERP applications in various industries as will be mentioned in this study. There are also some construction specific ERP studies in literature. These studies are mostly based on case studies for a specific module of ERP or a limited group of modules. Some other ERP studies in construction generally relate to cost effectiveness, productivity, and use of ERP systems in construction.

There are also less number of conceptual models presented such as a 3-Tier architecture model for construction ERP implementation (Shi and Halpin, 2003), and a 4-Tier architecture model for integration of Enterprise Resource Planning (ERP) and Project Management System (PMS) (Ryoo et al., 2007).

However, none of these studies have provided a general examination and comprehensive understanding of an ERP system in construction in terms of suitability, investigating the difficulties and determining the points that suits and does not suit to the construction business. Also, there has been no study completely identifying the suitability of ERP systems to the respective parties of the construction business.

1.4 Aim and Objectives of The Research

One of the major objectives of this thesis is to figure out the suitability of ERP system in construction business. In order to investigate the suitability of ERP systems, detailed literature survey will be conducted in different disciplines such as information systems, financials, computer science, manufacturing, automation, and construction. Also, available ERP software products and their capabilities to manage construction-specific needs will be reviewed and evaluated. This broad view approach aims to provide readers a complete set of information on ERP systems. Within this context, following are the objectives of this research study:

- To introduce ERP concepts and to mention the evolution of ERP systems.
- To investigate the adjustments and/or changes necessary for a successful implementation of ERP.
- To explain the basic features of ERP.

- To describe the requirements for ERP applications.
- To analyze the system selection process.
- To investigate the implementation process.
- To define costs and benefits of ERP systems.
- To address the issues regarding the future of ERP systems.
- To introduce ERP systems in construction.
- To discuss the ERP models proposed in literature.
- To analyze the benefits and risks of ERP applications in construction.
- To provide case studies on ERP applications.
- To discuss the difficulties in construction ERP applications.
- To discuss the overall suitability of ERP systems for construction business.

This study not only point outs specific deficiencies and concerns in construction ERP applications for researchers to explore, but also practically provides extensive knowledge of construction ERP to the respective construction business parties for their ongoing and prospective construction business applications.

1.5 Method of The Research

All above objectives of this research are achieved through literature survey. Some recommendations are proposed considering the limitations of the software packages and models both in literature and in commercial markets. In this context, some solutions are provided for some of the core activities carried out in a construction project. In addition, the roles of participants in construction are defined and the benefits each party can derive from ERP systems are identified. Following are the 60

activities performed to achieve the preset objectives:

- ERP concepts are introduced and the evolution of ERP systems is mentioned based on an extensive literature survey.
- Adjustments and/or changes necessary for a successful implementation of ERP are investigated in depth based on an extensive literature survey.

Requirements are examined under organizational basis and technological basis including the efforts and necessary steps related to change management, organizational culture, and the information systems (IS).

- Basic features of ERP are explained. Modularity of ERP is explained in terms of the dynamic structure integrating various enterprise systems with ERP, such as customer relationship management systems (CRM), knowledge management systems (KM), and decision support systems such as the advanced planning and scheduling systems (APS). These information are derived from the literature.
- Requirements for ERP applications are described such as company capacity, system requirements, and end-user requirements base on the literature survey.
- System selection process is discussed based on the literature survey. As one of the most critical issues, system selection is analyzed considering the selection criteria, selection steps, system evaluation, and understanding the needs for ERP systems.
- The implementation process is investigated based on an extensive literature survey. Since the process of implementing an ERP system involves early planning prior to the implementation, is also very costly, and necessitates employee commitment, ERP implementation is regarded as an organizational and strategic problem. This problem is investigated extensively in terms of the strategies to be developed for implementing ERP systems, common implementation methodologies, the reasons of implementation failures, critical factors for success for a successful implementation.
- Costs and benefits of ERP systems are defined based on the systems in the literature and the commercial markets. ERP applications in various industries are mentioned, both foreign and domestic ERP software providers are examined.
- Issues regarding the future of ERP systems are addressed based on the information obtained through the literature survey.
- ERP systems in construction are introduced based on an extensive literature survey.

- ERP models proposed in literature are discussed and their most important features are explored.
- Benefits and risks of ERP applications in construction are analyzed based on the proposed models in the literature.
- Some case studies on ERP applications are provided both from literature and from the commercial markets.
- Difficulties in construction ERP applications are discussed. Difficulties in using current ERP products, limitations in important activities such as scheduling, and accounting, problems in integration with non-ERP systems, difficulties in IT applications, data collection and accuracy are addressed.
- The overall suitability of ERP systems for construction business is discussed in depth. The construction industry is a highly fragmented industry involving many participants including owner, contractor, designer, subcontractors, etc. The uniqueness of the industry prevents the direct implementation of many methods and concepts developed in the manufacturing industry. Such uniqueness leads and forces researchers to develop their own science base, principles, and application procedures for the sustainability of this major industry. In the context of this research study, firstly the fragmented nature of construction business has been explained, then ERP systems in construction business has been mentioned identifying their objectives, benefits, risks, conceptual models and current ERP systems in use. Major difficulties of ERP systems in construction are pointed out; and some recommendations are provided for each party involved in a construction project.

1.6 Scope and Limitations

This research study is mainly based on the literature survey, the researcher's experience and expertise in the construction sector as an assistant project manager, interviews with senior managers (Chief Financial Officers, Vice Presidents, and Senior Project Managers) of some construction companies in United States and software engineers (individulas working in private companies and researchers from major Turkish universities) specialized in ERP system developement and applications in Turkey, interviews with major worldwide ERP and project

management system providers, and is in regards to determining relationships and mutual influence of:

- Characteristics of ERP Systems including:
    - ERP system selection and implementation process
    - Cost and benefits of ERP systems
    - ERP vendors in international and domestic market
- Definition of construction business stereotypes
- Needs of construction business
- Benefits and Risks of ERP in construction business
- Possible difficulties of ERP systems in construction
- Evaluation of current ERP products in construction

All these subjects will be investigated in order to figure out the construction industry-specific problems, difficulties in ERP systems in construction business, possible solutions in order to cope with these problems, and examination of suitability of ERP systems in construction business including industry-wide discussion and each respective construction party.

This study does not concern and focus on a certain module of an ERP system, nor examine a particular ERP product in the market, as it applies a holistic approach to the ERP systems in construction.

1.7 Research Calendar

Main objectives carried out in this research study are listed in Table 1.1. The associated content of the activities are also broken-down.

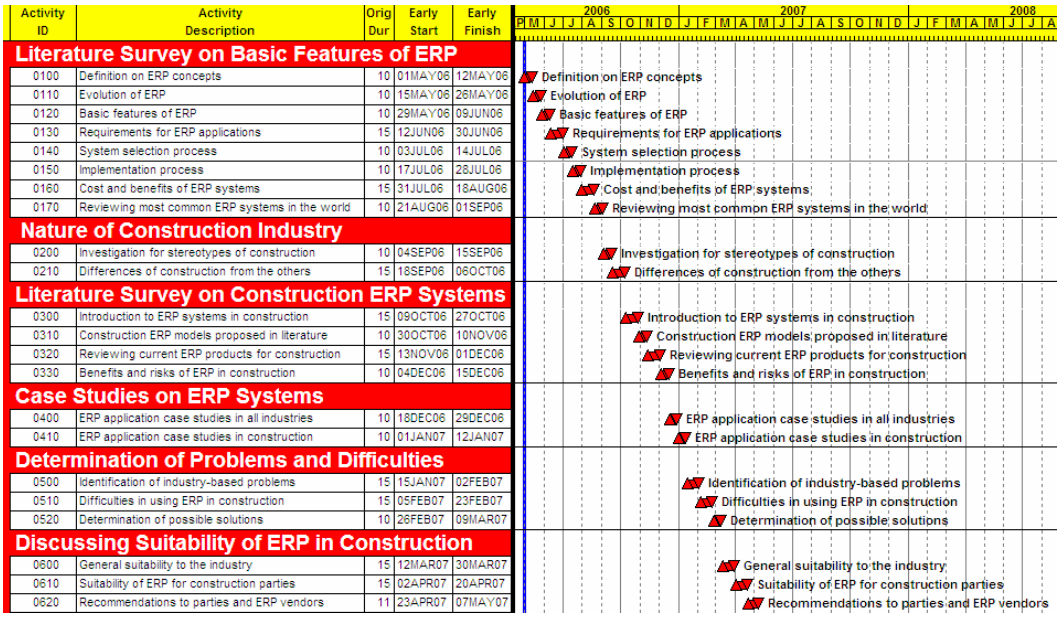

Figure 1.1 Stages of the research

2. ENTERPRISE RESOURCE PLANNING (ERP) SYSTEMS

This chapter provides a comprehensive definition and explanation of Enterprise Resource Planning (ERP) System and its application including all stages and phases throughout the lifetime of an ERP system.

2.1 Introduction to ERP Systems

Today's market conditions in various industries strongly demand new techniques and business solutions for companies to keep their competitiveness. In order to meet owner requests, customer needs and desires, faster product development, more customized manufacturing, quicker distribution (Gencel, 2003), accurate job progress projection, improved communication and timely manner are essential elements for the competitor companies of a particular market. While the market is emerging alternate ways of doing business, customer expectations are significantly increasing, which makes companies increase business standards and service quality, as well as versatility and diversity of services. Companies should be aware of the fluctuating environment of the market and rapid changes in technology, and also should be able to keep up with the changes to maintain their position at the competitive edge of the business (Thao, 2002). In order to keep the growth under control, organizations need integrated business solutions which enable them to maintain and improve their work process smoothly.

Enterprise resource planning (ERP) systems are considered as the most ambitious, advanced, and sophisticated use of information technology (IT) by business to date ,and are very important to companies because of the efficiency and uniformity procedures and potential competitive advantage they offer, as well as the significant cost, risk, and time commitments associated with them (Benco, 2004).

ERP systems consist of many functional modules, which are all linked to a common database, handling a host of corporate functions such as finance, human resources,

materials management, sales and distribution (Slater, 1998). Most ERP packages also allow users work on multiple language and currency (Gencel, 2003) providing a capability of international operations and operations in different locations all over the world within the same unique integrated system. The ERP system enables employees to share information across the whole organization (Thao, 2002) on real-time basis and at one time, and also update the information as changes are being made.

2.2 Definition of ERP Systems

Enterprise Resource Planning is defined by Kremzar and Wallace (2001) as:

> "An enterprise-wide set of management tools that balances demand and supply, containing the ability to link customers and suppliers into a complete supply chain, employing proven business processes for decision-making, and providing high degrees of cross-functional integration among sales, marketing, manufacturing, operations, logistics, purchasing, finance, new product development, and human resources, thereby enabling people to run their business with high levels of customer service and productivity, and simultaneously lower costs and inventories; and providing the foundation for effective e-commerce"

ERP systems are generally used to optimize a company's business whereby optimization can be seen as the process of reducing the possibility of potential problems and improvement of the business by utilizing the integration between business units (Steyn, 2004). "What ERP really does is organize, codify, and standardize an enterprise's business processes and data. The software transforms transactional data into useful information and collates the data so that it can be analyzed" (Norris et al., 2000; cited in Thao, 2002).

There are various definitions of ERP which can be found in Table 2.1 below.

Table 2.1 Definitions of ERP

Author	**Definition**
Szitas (2005)	A unified information system, performing all information-processing tasks of a company and realizing an integration of the whole corporation.
Marnewick and Labuschagne (2005)	A packaged business software system that lets an organization automate and integrate the majority of its business processes, share common data and practices across the enterprise and produce and access information in a real-time environment. The ultimate goal of an ERP system is that information must only be entered once.
Gencel (2003)	A software solution that carries out all the functions of an enterprise to succeed in organizational goals as a collection of integrated subsystems.
Kapp et al. (2001)	A system of integrated procedure, rules and algorithms designed to function consistently time and time again.
Brislen and Krishnakumar (1999; cited in Mayer, 2000)	A broad set of activities supported by multi-module application software that help…a business manage the important parts of its business.
Everdingen et al. (2000 cited in Wu and Wang, 2003)	A software package which promises enabling a company to seamlessly integrate the data and information flowing throughout its entire organization including financial and accounting, human resource, supply chain, and customer information.
Al-Mudimigh (2002)	Integrated information system software comprised of several modules that share a central database, designed to automate business processes across the enterprise.
Brown and Vessey (1999; cited in Beekhuyzen, 2001).	Online interactive system that can provide a 'total' solution to an organization's information systems needs by addressing a large proportion of business functions.
Pawlowski et al. (2000; cited in Beekhuyzen, 2001)	Shared information systems, which are systems that cross typical organizational boundaries and therefore have multiple users and stakeholders who have different cultures and approaches to work.
Koch et al. (1999)	A single integrated software package that runs off a single database so that various departments can easily share information and communicate.

2.3 Evolution of ERP Systems

Enterprise resource planning (ERP) is originated from manufacturing and production planning systems (Fitzgerald, 1992). The acronym “ERP” for enterprise resource planning was defined in 1990 by Gartner, Inc. (Gould, 2002), which is the leading industry provider of research and analysis services.

First enterprise-level solutions have been obtained, apparently, in 60-s as custom-made IS for inventory control (IC) based on mainframes. Examples include IBM IMS in 1968, and Cullinet Software IDMS network systems in 1971 (Zykov, 2001). In 1960’s, inventory control was considered as the most important part of business process, therefore most of the software solutions aimed to help in inventory management, and inventory management were generally handled by tools called BOM (Bill of Materials) processors (Gencel, 2003), provided by IBM.

In the 1970’s, it became increasingly clear that companies could no longer afford the luxury of maintaining large quantities of inventory. This led to the introduction of material requirements planning (MRP) systems. MRP represented a huge step forward in the materials planning process (Umble et al., 2003).

Techniques for capacity planning were added to the basic MRP system capabilities. Scheduling techniques for the factory floor and supplier scheduling were incorporated into the MRP systems. When this occurred, users began to consider their systems as company-wide systems. These developments resulted in the next evolutionary stage that became known as closed loop MRP (Oden et al., 1993; cited in Umble et al., 2003).

In the 1980’s, companies began to take advantage of the increased power and affordability of available technology and were able to couple the movement of inventory with the coincident financial activity. Manufacturing resources planning (MRP II) systems evolved to incorporate the financial accounting system and the financial management system along with the manufacturing and materials management systems. This allowed companies to have a more integrated business system that derived the material and capacity requirements associated with a desired operations plan, allowed input of detailed activities, translated all this to a financial

statement, and suggested a course of action to address those items that were not in balance with the desired plan (Ptak and Schragenheim, 2000).

By the early 1990's, continuing improvements in technology allowed MRP II to be expanded to incorporate all resource planning for the entire enterprise. Areas such as product design, information warehousing, materials planning, capacity planning, communication systems, human resources, finance, and project management could now be included in the plan. Hence, the term, ERP was coined. And ERP can be used not only in manufacturing companies, but in any company that wants to enhance competitiveness by most effectively using all its assets, including information (Ptak and Schragenheim, 2000; Shankarnarayanan, 2000).

Although the terms MRP, MRP II and ERP are being used throughout most organizations, often people are confused and cannot distinguish the differences between the three. According to Boyle (2000; cited in Thao, 2002), MRP is an inventory control and production planning system designed for ordering and scheduling dependent demand of inventory, which includes the following components: Master Schedule, Bill of Material and Inventory record file. MRP II is just an expansion of the MRP system with three new capabilities including financial analysis, feed back loops, and marketing plans. Finally, ERP is also an extension of MRP II with additional capabilities, such as better graphical user interface, the use of relational database, fourth language generation, open system portability, and is much more integrated than MRPII. In addition, Kapp et al. (2001), stated that the differences between ERP and MRP II is the inclusion of a variety of manufacturing processes within ERP, in which modern ERP software is able to handle both discrete work orders and flow orders, JIT (Just in Time) and MRP, EDI (Electronic Data Interchange), and hand-entered orders.

The scope of ERP offerings expanded in the mid-1990s to include other **back-office functions** such as order management, financial management, warehousing, distribution, quality control, asset management, and human resources. The range of functionality of ERP systems has further expanded in recent years to include more **front-office** functions, such as sales force, electronic commerce, and supply-chain systems (Hare, 1999).

ERP was extension of MRP II to cover the range of activities (Engineering, Finance, Human Resources, Project Management, Quality etc.) within any enterprise. Figure 2.1 illustrates the evolution of ERP from BOM processor to ERP II.

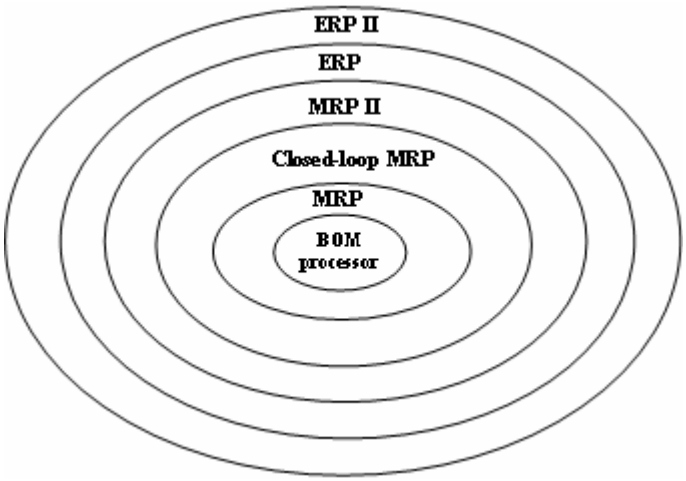

Figure 2.1 The evolution of ERP (adopted from Kremzar and Wallace, 2001; Gencel, 2003)

ERP II is simply the next destination in the evolution of resource planning systems. ERP II is the iteration that adapts ERP to the Internet-based world of today and tomorrow through changes in functionality, technology, and architecture. The most apparent change from ERP to ERP II is a change in focus from one that is totally enterprise-centric and preoccupied with internal resource optimization and transactional processing to a new focus on process integration and external collaboration (Wheller, 2004).

Internally, ERP II integrates separate and disparate systems so that business processes can be connected in a manner that is seamless and transparent to users at the application or user interface level. Collaborating-commerce (c-commerce) is enabled by ERP II application deployment strategies and relates to information that is exchanged when two or more businesses exchange information electronically via the Internet. The applications, process, and data of all collaborating businesses are integrated and loosely connected to facilitate near real time sharing of business data (Wheller, 2004).

2.4 Objectives of ERP Systems

ERP systems are distinguished for their e-business support, integration approach, flexible modular architecture, and openness for horizontal accommodation of wider scope of tasks, and for vertical building of sophistication and intelligence (Bakry and Bakry, 2005). The enterprise resource planning intends to support one time entry of information at the point where it is created and make it available to all the systems that need it (Grad 1999; cited in Lee et al., 2004).

According to the literature, the last decade have seen a dramatic growth in the use of ERP systems, in particular by world-class organizations eager to develop an international information systems strategy. According to Skok (2001; cited in Kenaroglu, 2004), Shanks et al. (2003), Koch (2002; cited in Thao, 2002), and Paquin (2002; cited in Steyn, 2004), key drivers of the need for ERP implementation are as following:

- Legacy systems and Year 2000 (Y2K) system concerns
- Globalization of business (need for a common platform)
- Increasing national and international regulatory environment e.g. European Monetary Union
- Need for integrated information and data visibility
- JIT (Just in Time) philosophy, BPR (Business Process Re-engineering), standardization (e.g. ISO 9000) and improvement of process
- Scaleable and flexible emerging client/server architectures
- Trend for collaboration among software vendors and increased customer responsiveness
- Operating cost reduction
- Improved decision making

The trade press cites Y2K problem as the major reason in the upsurge of the demand for ERP systems in the mid-1990s (Caruso, 1998). Due to limited space, early computer systems are programmed to store only the last two digits of the year. Early engineering failed to realize that the year 2000 will pose a threat, in which the last

two digits of the year will become zeroes causing confusion and leading to system malfunction. Therefore, implementation must take place before the year 2000 to prevent system failure (Thao, 2002). Another reason for the need of ERP systems implementation is stated as to simplify and standardize IT systems as well as to provide accurate data flow from operations and business functions in order for improving the interactions with their customers and suppliers as their new strategic advantage. On the other hand, the major underlying consequence is, of course, the improvement in the business process that would stimulate the overall productivity for the enterprise. Therefore, ERP systems are described as business solutions rather than solutions for information systems problems such as Y2K (Caruso, 1998).

With the dawn of e-business architecture and the release of new concepts such as Supply Chain Management (SCM), Knowledge Management (KM), and Customer Relationship/Service Management (CRM) over the internet, ERP systems have evolved to become advanced business application paradigm recently known as ERP II, opening a new era in the New Economy (Gartner, 2000). New Economy is the term used for defining the intensive economic environment where competency is fed by technological phenomena such as e-business, e-commerce, SCM, CRM, or etc. Boubekri (2001; cited in Kenaroglu, 2004) claimed that choosing the right ERP system for a company is the key for gaining the competitive edge. ERP is a key technology enabler to integrate demand, supply, manufacturing, scheduling, transportation, and network optimization functions of corporations.

2.5 Basis of ERP

The implementation of ERP systems ultimately results in changes to processes (business-oriented activities), which in turn inflicts changes to work practices (people-oriented activities) (Beekhuyzen, 2001). “Implementing ERP requires major changes to organizational, cultural, and business processes” (Norris et al., 2000; cited in Thao, 2002). Kremzar and Wallace (2001) also state that “most companies implementing ERP must undergo massive behavior change to be successful.” They continue by saying that “many things must be done differently, and this kind of transformation is never easy to achieve”.

Within the context of this study, basic requirements and/or changes necessary for a

successful implementation of ERP are investigated under organizational basis and technological basis.

2.5.1 Organizational Basis

Pawlowski et al. (2000; cited in Mayer, 2000) indicate that ERP packages can be considered shared information systems, which are systems which cross typical organizational boundaries and therefore have multiple users and stakeholders who have different cultures and approaches to work.

ERP's enable automating the tasks involved in performing a business process so it is integral that implementors start with a clear articulation of the business problems being addressed. Not only do the business functions need to be identified, the more subtle issues such as the company's corporate culture and management style must be examined (Slater, 1999; cited in Beekhuyzen, 2001) to enable a holistic view of the implementation.

In order to have an ERP system work smooth and properly, organizations need to be fully aware of the process prior to implementation. Organizational basis are identified as change management, organizational culture and organizational knowledge in this study in order to provide fundamental knowledge of an organization, and emphasize potential conflicts in a generic manner.

2.5.1.1 Change Management

Change management plays a major role in the successful implementation of an ERP system (Marnewick and Labuschagne, 2005). Major change management issues may be named into four groups as following: user resistance to change, scope changes, business process changes, and version management.

Resistance to change is one of the major issues that all ERP projects will face (Workforce, 2002). User resistance to implementation due to data input problems has led to ERP vendors to devote increasing attention to making their systems easier to use. Some benefits of data input changes have been identified as the ability to gather data once and input it straight into a computer-based environment. Consequently, there is tension between the benefits of changing and the disruption that can occur in

an organization as a result of accommodating the changes (O'Leary 2000).

All ERP projects are subject to **scope change** at some time during the lifecycle. The key to successful ERP implementation is to effectively manage the change of scope process (Project Management Institute, 2000). Scope changes must go through a system of approval against the original ERP modeling and design. This ensures that the proposed changes are necessary and appropriate and that the integrity of the ERP system is maintained. (Marnewick and Labuschagne, 2005).

ERP systems bring with them **business process changes**. The key business drivers forcing business process changes are replacing legacy systems, gaining greater control and managing globalization across the enterprise. Companies must have a more accurate and timely information flow to meet these demands (Hooks, 2002). The business processes will change as the ERP system is installed and also as the ERP system evolves and matures. The business processes will also change as the users become familiar with the system (Marnewick and Labuschagne, 2005).

When ERP applications are introduced, a number of new change management issues are encountered that are associated with maintaining and reconciling custom and packaged applications. Generally speaking, **version management** helps an organization to effectively manage version control and security issues that are typical to a software development and maintenance project (Marnewick and Labuschagne, 2005).

2.5.1.2 Organizational Culture

The word “culture” is typically associated with societies and nations, or relating to ethnic or regional groups. However, it is also applied to other human groups such as organizations, professions, or families. Clarke et al. (1981; cited in Clemmons, 2005) broaden the definition of culture to argue that it is constituted and expressed through institutions, social relations, customs, materials, objects, and organizations.

The literature suggests that all IS implementations now considers the important human, social and organizational factors that exist in the implementing environment (Avison et al., 2001; cited in Beekhuyzen, 2001). Inclusion of these factors in the ERP implementation process can enable the implementation team to better

understand the situation and therefore account for the ‘organizational culture’. Understanding these factors can help to improve the chance of success in ERP systems implementation.

Organizational culture may be defined as a patterned system of perceptions, meanings, and beliefs about the organization which facilitates sense-making among a group of people sharing common experiences. It emerges from the social interaction of organizational members and is the product of shared symbols and meanings (Bloor and Dawson, 1994; Bright and Cooper, 1993; cited in Beekhuyzen, 2001).

The culture within an organization plays a major role and influences the individual user. ERP systems break down all functional barriers within an organization and users are required to be multi-skilled and multi-managed. This means that it is often difficult to implement an ERP system in an organization with strict hierarchical structures and line reporting. The culture of the organization must first be changed for the ERP system to be successful (Marnewick and Labuschagne, 2005).

2.5.1.3 Organizational Knowledge

Selecting and managing an enterprise system requires a wide range of knowledge. Rosemann and Chan (2000; cited in Kenaroglu, 2004) listed five different types of knowledge for successful management of enterprise systems in their study. These types of knowledge during an ERP system software implementation project to be kept in mind are: business knowledge, technical knowledge, product knowledge, company-specific knowledge, and project knowledge.

Once ERP adoption decision has been made, in order to provide effective utilization of the information through the ERP life cycle (selection-implementation-maintenance), the use of knowledge management has been suggested by the academic community in order to support ERP system implementation. (Kenaroglu, 2004).

Knowledge management is concerned with the generation, representation, storage, transfer, transformation, application, embedding and protecting of organizational knowledge and establishing an environment and culture whereby knowledge can evolve (Schultze, 1998). Chan and Rosemann (2001; cited in Beekhuyzen, 2001)

argues that knowledge resources can be better managed by revealing the transparency of what knowledge is required at which point in time during the ERP implementation phase and where the knowledge resides.

2.5.2 Technological Basis (Information Systems)

An ERP system is a combination of the following functions: application integration, which enables data to be communicated automatically among applications; internal integration, which enables data to be stored centrally in an integrated database to be accessed by anyone in the organization who needs it; external integration, which enables the internal organizational network to be connected to all or most business partners outside the organizational boundary; and automation enabled by the applications themselves. Thus, the transformation from a non-ERP system into an ERP system is performed through these ERP functions. While all data of all functional departments reside in a central database, functional groups use the applicable software for their departments. The enterprise resource planning uses wide area networks (WANs) that enable the coordination of company activities globally (Lee et al., 2004).

Information systems are the means by which organizations and people, utilizing information technologies, gather, process, store, use and distribute information in business processes (Gencel, 2003). According to Alter (1999; cited in Beekhuyzen, 2001) an information system is “a combination of organizational goals, work practices, information, people and information technology.

Information Systems (IS) research suggests that IS’s and their supporting information technologies have crucial importance to the success of each organization (DeLone and McLean, 1992; cited in Beekhuyzen, 2001).

Organizations employ information systems in three different ways:

- Custom-built Systems
- Off-the-shelf Systems
- Hybrid Systems

Custom-built systems are originated from company’s own business processes.

Organization develops or has developed information systems customized to its own processes. Off-the-shelf systems are standardized systems according to common best business practices and developed to satisfy many (worldwide or sector-wide) organizations' business requirements. A Hybrid System can be defined as a combination of others. Standard part of the information systems is acquired, and the rest is developed custom. These two portions can be in varying amounts (Gencel, 2003).

2.6 Modularity of ERP

The architecture of an ERP system is of modular construction that is of dynamic structure, which makes it flexible to modifications and expansions (Bakry and Bakry, 2005).

ERPs are Information Technology (IT) whose primary function is the integration and standardization of information and processes within the internal organization and throughout its supply chain (Davenport, 2000). This is done by a collection of application modules communicating with each other directly via one central database from which all modules draw, manipulate and update data (Bingi et al., 1999). The central database integrates and homogenizes information enabling the organization to be truly accessible to everyone across diverse organizational functions, units, and geographic boundaries in near real time (Dillard and Yuthas, 2006).

2.6.1 Materials Management

Materials management is the process of planning and control of all necessary efforts to ensure that the correct quality and quantity of materials and installed equipment are appropriately specified in a timely manner, obtained at reasonable costs, and made available to users when needed (Business Roundtable, 1982). Similarly, the materials management system (MMS) combines and integrates the individual functions of material requirements planning, materials takeoff, vendor evaluation and selection, purchasing, expediting, shipping, materials receiving and inventory, and materials distribution (Bell and Stukhart, 1986; cited in Lee et al., 2004).

2.6.1.1 Material Requirements Planning (MRP)

Material Requirements Planning (MRP) is a software-based production planning and inventory control system used to manage manufacturing processes (Wikipedia, 2007a). An MRP system is intended to simultaneously meet 3 objectives:

- Ensure materials and products are available for production and delivery to customers.
- Maintain the lowest possible level of inventory.
- Plan manufacturing activities, delivery schedules and purchasing activities.

2.6.1.2 Manufacturing Resource Planning (MRP II)

The next development step in the comprehensive control systems was a **Manufacturing Resource Planning (MRP II)**. The approach of the MRP II was extended towards the more technical areas of an organization that covered the product development and production processes like capital and labor availability in the production activity. (Helmut et al., 2000; cited in Salmenpaa, 2006).

Management business rules for strategic planning can be set, and enforced by MRP II. Sales and Marketing can incorporate sales goals that fit material and capacity constraints. Relationships can be developed with vendors to improve purchasing just in time. Inventory shortages can be seen before they happen, with communications to customers to get approval of substitutions that will get a part that does the same thing, on schedule. Accounting and finance departments get accurate costs, and predict cash flow. Engineering department must audit and feed in accurate data on production methods in detail, such as bill of material, rates and lead times (Wikipedia, 2007b).

2.6.2 Customer Relationship Management (CRM)

Customer Relationship Management (CRM) is the broad category of concepts, tools, and processes that allows an organization to understand and serve everyone with whom it comes into contact. Definition of “customer” may refer to suppliers, partners, investors, employees, and other possible participants. Each of these groups has specific and unique requirements when dealing with your organization. CRM is

about gathering information that is used to serve customers—basic information, such as name, address, meeting and purchase history, and service and support contacts (CRM, 2007).

CRM integrates the business processes and it allows the company staff to work with real-time customer information, greatly enhancing the quality of service. And it establishes a seamless flow of customer information to and from the company's e-business platform – including e-selling, e-procurement, supply chain management, strategic enterprise management, financial management, and even human resources (SAP AG, 2006). Major CRM providers such as SAP (mySAP CRM) and Oracle (Oracle CRM) provide business solutions for many markets including aerospace and defense, automotive, banking and financial services, chemicals, consumer products, engineering and construction, healthcare, higher education and research, insurance, media, mining, oil and gas, pharmaceuticals, public sector, and telecommunications.

2.6.3 Other Functional Modules of ERP Systems

The integrated nature and dynamic architecture of ERP brought ideas for the improvement of the original ERP systems. These improvements include integrating various enterprise systems with ERP, such as customer relationship management systems (CRM), knowledge management systems (KM), and decision support systems such as the advanced planning and scheduling systems (APS) and the (online analytical processing systems (OAP) (Bakry and Bakry, 2005).

ERP Modules may be grouped according to their functions. Table 2.2 shows the comprehensive list of ERP modules categorized per functions based on Voordijk et al. (2003), Kapp et al. (2001), Kenaroglu (2004), and O'Connor and Dodd's (1999) classifications and studies.

Table 2.2 ERP Modules (Adopted from Voordijk et al. (2003), Kapp et al. (2001), Kenaroglu (2004), O'Connor and Dodd (1999)).

Financials	**Operations and Logistics**
Accounts Receivable and Payable	Inventory Management
Asset Accounting (FI-AA)	Materials Management (MM)
Cash Management and Forecasting	Plant Maintenance (PM)
Cost-element and Cost-center Accounting	Production Planning (PP)
Executive Information System	Project Systems (PS)
Financial Consolidation	Purchasing
General Ledger	Quality Management (QM)
Product-cost Accounting	Routing Management
Profitability Analysis	Shipping & Tracking Orders
Profit-center Accounting	Vendor Evaluation
Standard and Period-related Costing	Resource Planning
Treasury Management (TR)	Rough Cut Capacity Planning
Investment Management (IM)	Material Requirements Planning (MRP)
Human Resources	Detailed Capacity Planning Module
Human Resources (HR)	Production Activity Control (PAC)
Human-resource Time Accounting	Manufacturing Execution System (MES)
Payroll	Issuing Material to Jobs
Personnel Planning	Controlling (CO)
Travel Expenses	Service Management (SM)
Environment, Health, Safety Management (EH&S)	Workflow (Wkflw)
Sales and Marketing	**Decision Support Systems**
Order Entry and Product Management	Advanced Planning & Scheduling Systems (APS)
Quoting & Pricing	Online Analytical Processing Systems (OAP)
Sales & Distribution (SD)	Business and Strategic Planning Module
Sales and Operations Planning	Executive Decision Support Module
Customer Relationship Management (CRM)	
E-Commerce Modules	
Information systems	
Data Management System (DMS)	
Classification System (Class)	
Knowledge Management (KM)	
Electronic Mail (Email)	

One particular ERP system may require additional modules, or may need to exclude some certain models if not applicable. Determination of necessary modules will be discussed in 2.8 System Selection.

2.7 Requirements for ERP Applications

ERP Implementation requires extensive feasibility studies due to its wide-integrity and sophistication. Several items need to be deliberately reviewed before taking an action, such as functional complexity, level of automation, number of users, number of sites, level of readiness with old/special software systems, characteristics of project participants, level of consultancy service (Gencel, 2003). Requirements for ERP applications are described below as company capacity, system requirements, and end-user requirements.

2.7.1 Company Capacity

Company capacity includes type of business, size of the company, number of employees, monetary value of operations, annual cash flow, assets, current use of technology, need for integrity, and business participants. Implementation process should be perfectly planned in order to face with less problems since it is not possible to foresee every aspect of the implementation. This requires extreme attention on implementation process.

Company business functions, structure, market shares, operations, financial strength, company culture, innovative potential, business partners and other company values need to be investigated throughout the feasibility period of the ERP implementation in order to identify the best-fit system for a particular company.

Kraemmergaard and Rose (2002; cited in Kenaroglu, 2000) investigated the managerial competencies required for the complex interactions required to integrate an ERP system into an organization successfully. They concluded that a wide range of competences are required: personnel, business and technical. The competence mix should be expected to vary through the journey, and is often too much to expect of one person.

2.7.2 System Requirements

A particular ERP system requires specific configuration in order to utilize its functions. Not only the number of personnel and business network are indicating factors, but also strategic planning of the company plays significant role in defining

the system configuration depending on the company's trend to extend the business. The implementation of ERP systems typically requires that cross-functional languages and terminology of an organization be standardized so that a common, organization-wide database can be built. Conversely, standardization through ERP leads theoretically to the establishment of one common language and the management of different types of interdependencies between organizational actors (Klaus et al., 2000; cited in Amrani et al., 2006). Utilizing a dedicated software system, ERP integrates all business components in a unique system, which does need to work perfectly.

ERP packages are primarily proprietary systems as opposed to open system architectures. This can limit the flexibility of the enterprise that adopts a particular ERP package. Approaches to process design depend on the enterprise software selected. Standardized processes such as SAP R/3 and PeopleSoft require the adopting firm to adapt its processes to the requirements of the software. SQL and Oracle are more accommodating and allow firms to tailor the software to existing processes (Kissinger and Foster, 2001; cited in Umble et al., 2003). System requirements for an ERP system may be discussed in two categories as following:

2.7.2.1 Hardware Requirements

All the ERP systems require separate **servers** for the database and application, often at least one database server but multiple application servers, in very typical 3-tier architecture. While choosing the right server, following needs to be checked (Ghosh and Ghosh, 2003):

- Finalize the architecture blue print so that you know how many servers are required.
- Finalize the backup and testing strategy.
- Get the ERP recommended minimum processing power of each of the servers.
- Understand data requirements.
- Talk to business managers to understand the growth plan of the organization and how data requirements might change.

Although most of the processing power may be on server and Intemet based front end, there is still a minimum requirements for the **client machines**. PC upgrade is required for every client machine as necessary. Also, printer upgrade is required as well.

2.7.2.2 Network Requirements

A network is a series of points or nodes interconnected by communication paths. Network requirement depends on number of factors like number of users, data speed requirements and distance from server among many other things. Some of the key issues while upgrading a network are the follows (Ghosh and Ghosh, 2003):

Bandwidth signifies the speed of the link between two nodes. Based on the data flow requirement between a client site and database or application server, it indicates the band-width requirement for that specific link.

While the data flowing thru a network, it accumulates some delay, which is called **propagation delay**, so system may need to be adjusted to minimize the delay.

Optimization of the **utilization** of the network is also necessary. Industry standard is that network is average utilized 60 to 70 percent, with a possibility of peak at 90 to 95 percent. System also needs to have an alternate path against an unexpected link failure.

In addition to items above, providing global support and security, global disaster recovery and failover need to be secured. It is required to balance between data availability and a well-controlled (also well secured) system (Ghosh and Ghosh, 2003).

2.7.2.3 End-User Requirements

To ensure that the users fully understand the necessity of using the system correctly all the time, a needs analysis should be done to evaluate the users' technical skills, their existing job processes and the impact the system will have on their jobs (Workforce, 2002). Training should include information about their new roles and responsibilities, the business objectives of the initiative and the projected benefit to

the company. Training plays a major role in the operation of the ERP system after implementation**.**

The users will be expected to work twice as hard during the implementation of the system. They still need to do their normal operational work to make sure the business continues to run smoothly and they need to give inputs to the different project teams of which they are a part. This causes the users to become overworked, tired and stressed. It must be pointed out to the users right at the start what the issues will be during implementation, and the rewards must be clearly stated. It will be necessary to remind the users regularly of the benefits of installing the ERP system (Urwin, 2001; cited in Marnewick and Labuschagne, 2005).

2.8 System Selection

ERP projects require serious commitment, comprehension and support from the top-management and dedicated staff throughout the project (Kenaroglu, 2004), which will lead the whole process. In order to find a system that is appropriate for an organization, a true selection process needs to be undertaken (Livermore et. al., 2002). Further to provide a unique ERP solution, it is inevitable for the user to introduce customizations on the system. ERP selection process is a serious business since ERP system implementations differ from installing dedicated software packages, because ERP software is process-based rather than function-based (O'Leary, 2002).

There are mainly two options to select an ERP system as following: All-in-one, best-of-breed. Each type has different advantages; however it is not possible to declare anyone as superior to the other one, since every business / company has a unique situation. Therefore, the selection may be all-in-one; or best-of-breed, then additional applications can be acquired from the same vendor the ERP system was bought, from another vendor closely collaborating with the first, from a third party vendor, built-in house or outsourced. Stefanou (2000) highlights the advantages of best-of-breed and all-in-one software as shown on Table 2.3:

Table 2.3 Advantages of Best-of-breed and All-in-one Software

All-in-one ERP software	Best-of-breed ERP software
Consistent integrated processes Upgrades compatibility Lower cost Implementation simpler Maintenance easier	Functionality enhanced Flexibility Possible competitive advantage Extended applications (SCM, CRM, DSS, etc) widely tested No dependence on one vendor

Kenaroglu (2004) mentions that ERP selection tips acquired from accumulated know-how prevents vendors' or consultant's domination and helps a company to avoid false starts. Kenaroglu (2004) also groups these tips as general, functional, and logistics tips.

The general selection tips include business strategy and planning, long-term organizational and top-management commitment to the project, needs assessment, formation of the selection team, consultation, time and cost constraints of the project, business requirements and technical requirements specification, integration of business planning with the ERP system, change management and organizational resistance, resource allocation to the selection process, the selection and evaluation methodologies. The functional tips are the issues such as the scalability, modularity and the functionality of the product, the underlying technology of the system as well as configuration and customization capabilities of the system, upgrade and maintenance issues, vendors' expertise on the industry, and also the functional aspect of the evaluation methodologies etc. Logistics tips basically involve the issues about consulting, vendor profile and strength, customer-base, reseller channel, training and support. The pre-cautions taken with consideration of these aspects would maintain the integrity of ERP selection process as a whole (Kenaroglu, 2004).

2.8.1 Criteria for System Selection

When ERP systems are carefully examined, 80– 90% of a particular system will be the same across different implementations, but 10–20% will be different and tailored to the specific needs of the enterprise (Ptak, 1999). Therefore, the company must

identify its critical business needs and the desired features and characteristics of the selected system. Two distinct methods can be used for system selection. One method is to implement some overall business strategy by focusing on the information technology infrastructure. Some companies, especially large ones, may derive their greatest benefit through the centralization of data and increased control. The other method is to determine the particular features that are required to run a specific business. So some companies, especially small and medium ones, may opt for software that closely matches the specific functions and processes of their business to more easily manage the business, increase efficiency of operations, and reduce costs (Ptak and Schragenheim, 2000).

Various studies have investigated critical factors for the selection and implementation of ERP systems (Al-Mudimigh, 2002; Shehab et al., 2004). With regard to ERP selection five main issues have been taken into account (Bakry and Bakry, 2005):

- The **basic features** of the ERP system software; technical aspects of software, flexibility, user-friendliness, scalability, adaptability, handling growth, extendibility
- The **application features** of the ERP in regards to specific business of the enterprise; upgradeability, interface with other systems, incorporation of latest technology, targeted business and business environment, fit with business processes, strategic justification, customer requirements and relations, supply chain processes, economic benefits
- The ERP **vendor's or supplier's market strength and support** to customers; corporate image and international orientation, market position and leadership, implementation and continuous support, improvement support, local support
- The ERP **implementation speed**; timeframe for implementation process, ability to provide smooth conversion
- The ERP **cost**; performance / price comparison, affordability

2.8.2 Steps in System Selection

According to Umble et al. (2003) and Kenaroglu (2004), following steps should be considered in system selection.

- Create the business vision,
- Define the selection team,
- Create a feature/function list (business requirements analysis),
- Create a software candidate list,
- Narrow the field to four to six serious candidates,
- Prepare selection criteria,
- Create the request for proposal (RFP),
- Review the proposals,
- Select two or three finalists,
- Have the finalists demonstrate their packages,
- Select the winner,
- Justify the investment,
- Negotiate the contract,
- Run a pre-implementation pilot, and
- Validate the justification.

2.8.3 Evaluation of ERP Systems

Gencel (2003) groups some important factors as strategic and operational level factors, in order to have a successful evaluation of an ERP system. **Strategic level** factors (Gencel, 2003) are listed below:

- ERP's contribution to business vision and strategy
- Alignment of business and technology strategy
- Flexibility and scalability of IT architecture

- Flexibility and adaptability of ERP solution to changing conditions
- Integration of business information and processes
- Identification of the various components and magnitude of the project's risk
- Impact of ERP on the decision making process
- Competitors' adoption of ERP
- Impact of ERP on cooperative business networks
- Estimation of future intensity of competition and markets deregulation
- Impact of the decision to implement or not an ERP system on the competitive position and market share
- Estimation of the total cost of ERP ownership and impact on organizations' resources
- Analysis and ranking of alternative options in terms of the competitive position of the organization.

Some factors to be considered in ERP evaluation at the **operational level** (Gencel, 2003):

Impact of ERP on:

- Transactions' costs
- Time to complete transactions
- Degree of business process integration
- Intra- and inter-organizational information sharing
- Business networks
- Reporting
- Customer satisfaction

Estimation of costs due to:

- User resistance
- Personnel training

- External consultants
- Additional applications
- System downtime

Another evaluation method is **STOPE view** method to evaluate ERP systems. STOPE stands for 'strategy, technology, organization (enterprise or company), people, and environment'. The STOPE framework has been developed as an integrating tool for issues concerned with the use of the digital technology (Bakry and Bakry, 2001). It has been used for the evaluation of different problems, including network security, e-readiness assessment, and recently for e-government planning.

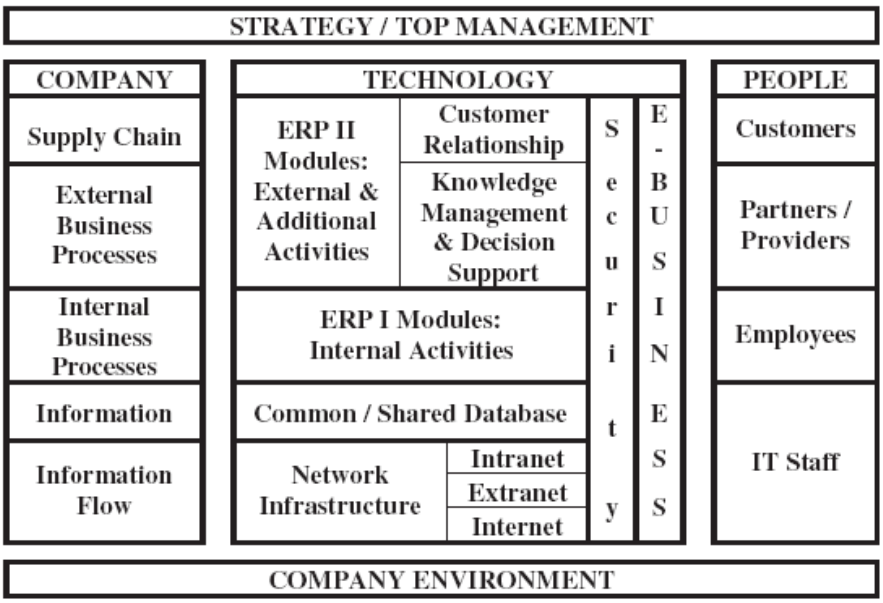

Figure 2.2 Integrated view of an ERP stystem (Bakry and Bakry, 2001).

Considering STOPE, and the ERP review given above, Figure 2.2 provides an integrated view of an ERP system in a modern company using e-business at the intranet private level, extranet special level, and Internet business level. The figure illustrates the following (Bakry and Bakry, 2001):

- 'strategy' is associated with the leadership of the top management which makes or breaks the success of ERP systems;
- 'technology' is given in layers starting with the network infrastructure (intranet, extranet, and the Internet), and moving up to the shared ERP

database, basic ERP modules (ERP I), and extended ERP modules (ERP II), in addition to the security and e-business (Web) interface with different users;

- 'organization or enterprise' operation is also described in levels that correspond to the technology layers: information flow is associated with the network, enterprise information corresponds to ERP database, and business processes are associated with ERP modules;
- 'people' associated with the enterprise include: the technical information technology (IT) staff, employees, partners and providers, and customers; and
- 'environment', that is, the professional conditions, both internal and external, under which the enterprise operates.

Consulting firms are providing many ERP software packages for companies to select. For instance, SoftSelect System is a consultant company that provides services to aid manufacturer and business in implementing their ERP system and other enterprise software. The services provided by SoftSelect System are through its real-time and unbiased software product data, whose database contains over 100 enterprise application packages and their capabilities (Thao, 2002). Consulting organizations have begun to specialize in a particular ERP installation process and are contracted by the ERP-adopting organization for the duration of the project (Caldas and Wood 1998; cited in Mayer, 2000).

2.8.4 Understanding the Needs for ERP

ERP systems are becoming more widely implemented in organizations of all types and sizes (Dillard and Yuthas, 2006). Despite research focusing primarily on implementation, the full impact of ERPs is not yet fully understood (Sia et al., 2002; cited in Kayas, 2006).

Generally, ERP implementations are performed by a project group in the companies. This project group reengineers the business processes within the ERP system capability boundaries and commonly presented to the rest of the firm after the implementation completion. One of the important points is understanding ERP system as a tool to improve our business processes, practices and discipline (Gencel, 2003). A proposed ERP system may hold great promise, but often fails to consider

how the users are likely to view this so-called improvement (Maurer, 2002; cited in Marnewick and Labuschagne, 2005). There are many reasons that contribute to the low success rates, yet one common aspect that prevails is a misunderstanding of what ERP entails (ComputerWorld, 2001; cited in Marnewick and Labuschagne, 2005). One of the biggest mistakes, made during the assessment the success of an ERP system, is perceiving newly implemented ERP system as an alternative for the existing business processes and comparing the systems before and after the implementation (Gencel, 2003).

Before implementing an ERP system, companies need to clearly recognize their expectations and timeframe. Most organizations realize the potential of ERP systems, yet struggle to materialize real benefits. One out of four ERP projects is over budget and some 20% are terminated before completion. ERP projects often fail to achieve business objectives even a year after the system has been implemented. The return on investment (ROI) also takes six months longer than expected (Marnewick and Labuschagne, 2005). Surveys indicate that positive effects of ERP implementations appear at least 1 year after the “go live” date (Gencel, 2003).

The most common reason that companies walk away from multimillion dollar ERP projects is that they discover that the software does not support one of their important business processes (Koch et al. 1999). In order to avoid experiencing such a problem, companies must start with the right step by having a proper selection process.

2.9 Implementation of ERP Systems

The process of implementing an ERP system is not easy, involves early planning prior to the implementation, and is also very costly. Many implementation projects have failed due to lack of prior planning, employee commitment, and choosing the wrong ERP system (Thao, 2002). Careful evaluation is requisite before selecting and implementing an ERP package because ERP is expensive and once ERP implemented, it is difficult and expensive to undo (Wu and Wang, 2003).

ERP implementation is not only a technical problem but also an organizational and strategic problem. Successful ERP implementation must be based on some requisites, including: reshaping how business is done, standardization and integration across

business units, and business process reengineering (Markus, 1997; Willcocks and Sykes, 2000). Thus ERP implementation will enable organizational change. Along with an organizational transition to ERP, whole departments must be retrained, job redefined, and procedures discarded or rebuilt from scratch (Deutsch, 1998), ultimately transforming core processes (Caldwell and Stein, 1998). Therefore, the ERP implementation outcomes (including implementation rate, package (vendor) selection, and perceived satisfaction) could be affected by organization characteristics (such as industry sector and enterprise size). Figure 2.3 shows the relationship between company characteristics and ERP implementation outcomes below:

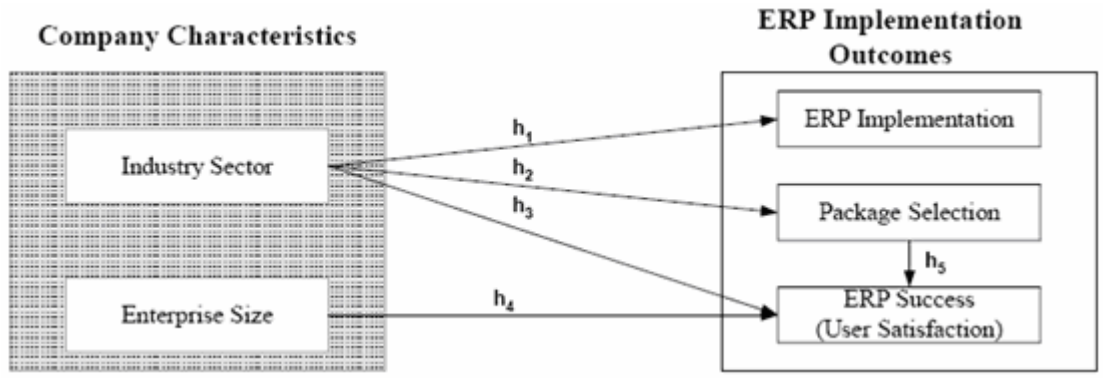

Figure 2.3 Relationship between company characteristics and erp implementation outcomes (Wu and Wang, 2003)

Gencel (2003) identifies **pre-implementation activities** below, assuming that the system selection and justification process has been completed.

- Organizing the implementation project. Setting up the implementation team and stock it with your company's smartest workers.
- Deciding on the implementation approach.
- Defining the performance measures for the new system.
- Creating the initial detailed project plan. The implementation team prepares a schedule for the entire project and makes sure that all resources will be available as needed.
- A clear statement of work or scope of the project is necessary.

- Educating key individuals.
- Assessing the integrity of the existing data.

2.9.1 Strategies for Implementing ERP systems

The implementation of an ERP changes the way organizations do business and how people carry out their work. Different implementation strategies may be adopted in implementing ERP systems in organizations (Koch et al. 1999).

2.9.1.1 Standard and Customized Implementation

Standard ERP Package Implementation involves adaptation of the ERP package to suit the user requirements. This requires a thorough understanding of the technical aspects of the ERP package as well as the functional aspects of the business. The standard packages, already designed for **best business practices** by the ERP vendors mentioned in the previous section, are not to be expected to fulfill the company own business processes. Therefore, most of the time, company processes are changed to obey package functionalities (Gencel, 2003).

Customized development covers both the **custom-built** systems and the **hybrid** systems, which are also mentioned in literature as slam-dunk approach dictating the process design (Koch et al., 1999). In custom development, company develops or outsources its tailored ERP systems for business processes. In custom development, companies may achieve more suitable systems with respect to standard ERP Packages. However, custom development requires all software development steps including requirements specification, modeling, coding, testing etc. These critical steps may be highly demanding in terms of IT staff. Employing or outsourcing a qualified and large software development team cost outside the affordable level for the companies. During the upgrades of the system, most of the times the customization exercise has to be repeated and maintenance of consistency in changes becomes a problem. This makes it more difficult to implement the package and considerably increases the risks and associated costs and changes schedules. ERP vendors generally support their clients to enhance their ERP systems with newer versions developed periodically. Following the new technologies may be impossible for custom-built ERP systems (Gencel, 2003).

Customizations to an ERP product are overwhelmingly considered in a negative light, evidenced by the risk and expense attached to such a process (Markus and Tanis, 2000; cited in Mayer, 2000). ERP vendors do not support products which have been significantly modified, thus preventing the client from gaining potential upgrades to the system. The expense in self-upgrading, or performing the same modifications on a new product, are often unable to be justified as the initial set-up for the first version of an ERP package is astronomical (when compared to the poor first returns gained) (Stedman, 1999; cited in Mayer, 2000).

2.9.1.2 Comprehensive and Stage-wise Implementation

Comprehensive Implementation can be called “at-once” or “big bang” implementation. This approach enables organizations to cast off all their legacy systems at once and implement a single ERP system across the entire organization. This is the most ambitious and difficult of approaches to ERP implementation. (Koch et al., 1999) Project duration may be years, but all of the ERP functionalities and modules are implemented in parallel considering the necessary integrations (Gencel, 2003).

Step-wise implementation is the opposite of the comprehensive implementation. This strategy is also referred to in literature as “phased implementation” (Slater, 1999; cited in Beekhuyzen, 2001) or “franchise strategy”, and suits large or diverse companies that do not share many common processes across business units. Independent ERP systems are installed in each unit, while linking common processes. “Usually these implementations begin with a demonstration or “pilot” installation in a particularly open-minded and patient business unit where the core business of the corporation will not be disrupted if something goes wrong” (Koch et al. 1999).Companies choosing this kind of implementation aim to spread costs, risks, company resistance, improvements and integrations through several times of implementation and years. Generally modules are sorted sequentially and implemented partially (Gencel, 2003).

2.9.2 Conceptual Application Implementation Methodologies

Several researchers have developed process models of ERP implementation. The implementation of an ERP system implies that a company must focus on, evaluate and define relevant company processes in precise detail. Implementing the ERP system is itself a process that begins with planning for the system. After planning is complete, a project team embarks on and then moves through a number of discrete project phases (Parr and Shanks, 2000). After the system is up and running, there may be a post-implementation review and later a stabilization phase. As several authors, Markus and Tanis (1999), and Shanks et al. (2000), have stated that the implementation process of an ERP system is best conceptualized as a business project rather than the installation of a new software technology.

There are several implementation methodologies in literature, such as Classical Life Cycle Model, Prototyping Model, The Spiral Model (Gencel, 2003), Bancroft's Model (Bancroft, 1998), Ross' Model (Ross, 1998), Markus and Tanis's Model (Markus and Tanis, 1999), and Project Phase Model (Parr and Shanks, 2000).

2.9.3 Common Implementation Methodologies in Practice

As Gencel (2003) identifies, there are several implementation methodologies, four of which are discussed within this study. These methods are generated by Oracle, SAP, Ernst & Young, and Deloitte & Touche.

2.9.3.1 Oracle Application Implementation Methodology (AIM)

Oracle AIM (Applications Implementation Methodology) is Oracle's project management methodology. Oracle AIM consists of a project management methodology together with the underlying documentation templates that support the tasks you perform within this methodology. This combination of a methodology together with documentation templates makes AIM a powerful tool for assisting implementation participants in running and managing projects successfully. The methodology can be used for any other software implementations. (Oracle, 2007) AIM provides the tools needed to effectively and efficiently plan, conduct, and control project steps to successfully implement business applications. AIM tasks are

organized into processes. Each process represents a related set of objectives, resource skill requirements, inputs, and outputs. A task can belong to only one process. Project team members are usually assigned to a process according to their specialization and background (Gencel, 2003). Figure 2.4 illustrates the AIM processes and their respective tasks assigned in alignment horizontally.

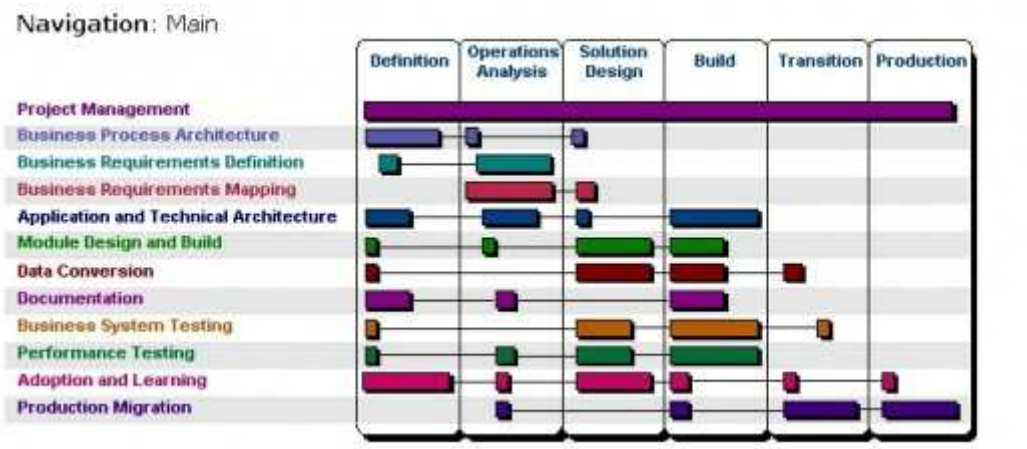

Figure 2.4 Oracle AIM Diagram (Oracle, 2007)

2.9.3.2 Accelerated SAP

Accelerated SAP (ASAP) is a standard methodology for efficiently implementing and continually optimizing SAP software. ASAP supports the implementation of the R/3 System and of mySAP.com Components, and can also be used for upgrade projects. It provides a wide range of tools that helps in all stages of the implementation project - from project planning to the continual improvement of your SAP System. The two key tools in ASAP are: The Implementation Assistant, which contains the ASAP Roadmap, and provides a structured framework for your implementation, optimization or upgrade project. The Question & Answer database (Q&Adb), which allows you to set your project scope and generate your Business Blueprint using the SAP Reference Structure as a basis. (ASAP, 2007)

ASAP focuses on the actual system implementation and the processes of the implementation steps. According to Shanks et al. (2003) ASAP roadmap includes the five sequential tasks of project; preparation, business blueprint, realization, final preparation, “going live” and support. This methodology ensures a successful implementation through structured project management methodologies and reporting

tools. The ASAP methodology can be customized to meet client specific requirements. Figure 2.5 depicts the steps in the ASAP methodology as defined by SAP AG (1999).

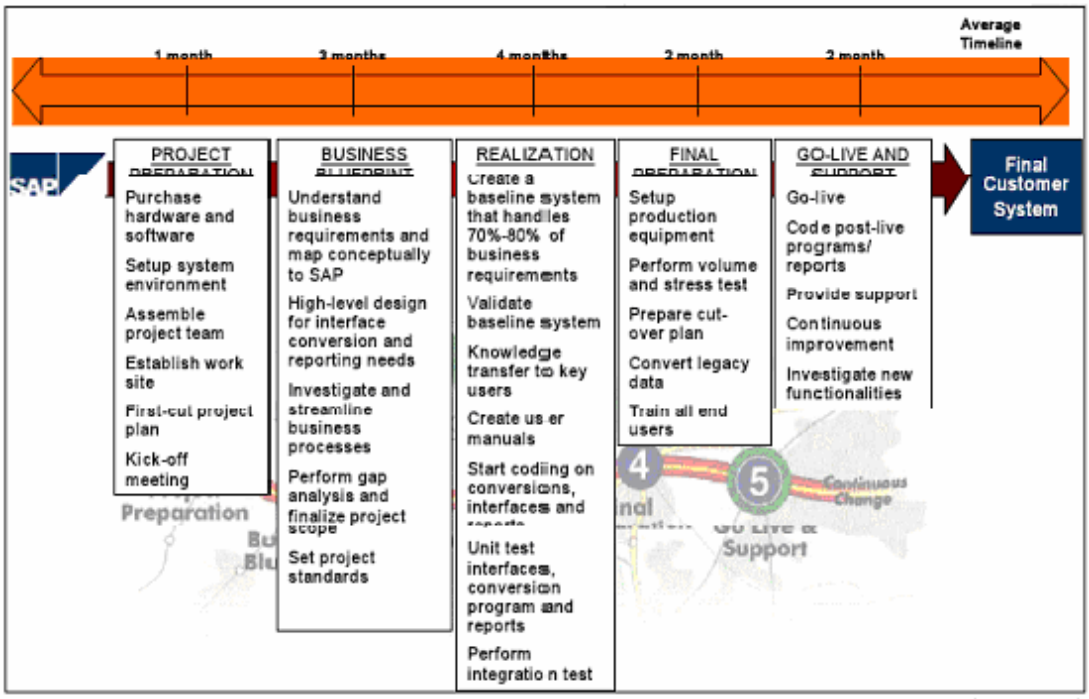

Figure 2.5 Steps in ASAP methodology (SAP AG, 1999)

2.9.3.3 Methodologies Provided by Consulting Firms

There are also ERP implementation methodologies provided by consulting companies. For instance, Ernst & Young LLP have developed a systematic way of approaching systems reengineering called “The Total Solution”, and Deloitte & Touche Consulting Group developed a methodology named Fast Track Workplan (Gencel, 2003).

2.9.4 Critical Factors for Success

Critical factors for success need to be defined in order for a successful implementation to be achieved. According to Bakry and Bakry (2005), the critical implementation factors have been associated with four main types of requirements as basic implementation requirements, implementation planning requirements, practical implementation requirements, and practical operation requirements.

Table 2.4 Critical factors for ERP implementation (Bakry and Bakry, 2005)

Requirements	Critical Factor
Basic Requirements	Strategic business case Project vision and scope Presence of a champion Top management support Learning from others Hiring consultant Sharing views with partners, suppliers, and customers Communications infrastructure
Planning Requirements	Evaluation of current state / legacy system Project management Implementation strategy Change management Business process change Team and tasks Training
Practical Implementation Requirements	Implementation approach Selection of software / vendor Installation and integration of ERP modules
Practical Operation Requirements	Operating the system gradually Monitoring and evaluation of performance Troubleshooting

There is no consensus among IS researchers regarding the conceptualization and operationalization of IS success evaluations (DeLane and McLean, 1992; Seddan, 1997; cited in Ifinedo and Nahar, 2006), and researchers (Grover et al., 1996; Myers et al., 1997; cited in Ifinedo and Nahar, 2006) have argued for the use of comprehensive measures. Ifinedo (2006) concludes that ERP systems success is a second-order factor best represented by the six dimensions as indicated by Figure 2.6.

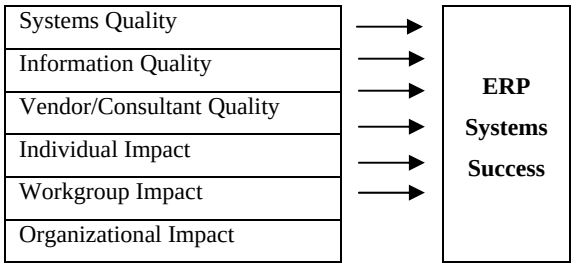

Figure 2.6 ERP system success framework (Ifinedo, 2006)

According to (Umble et al., 2003), critical success factors for successful ERP implementation are; clear understanding of strategic goals, commitment by top management, excellent project management, organizational change management, a great implementation team, data accuracy, extensive education and training, focused performance measures, and multi-site issues.

2.9.5 Implementation Process

ERP implementation steps are identified by (Umble et al., 2003) as follows:

- Review the pre-implementation process to date. Make sure the system selection process has been satisfactorily completed and all factors critical to implementation success are in place.
- Install and test any new hardware. Before attempting to install any software, it is essential to make sure that the hardware is reliable and is running as expected.
- Install the software and perform the computer room pilot. A technical support person from the software supplier will often install the software and run a few tests to make sure it is installed correctly.
- Attend system training. Software training will teach users the keystrokes and transactions required to run the system.
- Train on the conference room pilot. The conference room pilot exercises the systems and tests the users' understanding of the system. The project team creates a skeletal business case test environment which takes the business

processes from the beginning, when a customer order is received, to the end, when the customer order is shipped.

- Establish security and necessary permissions. Once the training phase is finished, during the conference room pilot, begin setting the security and permissions necessary to ensure that everyone has access to the information they need.
- Ensure that all data bridges are sufficiently robust and the data are sufficiently accurate. The data brought across from the old system must be sufficiently accurate for people to start trusting the new system.
- Document policies and procedures. The policy statement is a statement of what is intended to be accomplished; the procedural steps to accomplish that statement may be detailed in a flowchart format.
- Bring the entire organization on-line, either in a total cutover or in a phased approach. In a ‘‘cold turkey’’ approach, the whole company is eventually brought onto the new system. The entire company prepares for the cutover date, which would preferably be during a plant shutdown of one to two weeks. In a phased approach, modules/products/plants are brought on-line sequentially. After the first module/product/plant is live, procedures may be refined and adjusted, and then the remaining modules/products/plants are sequentially implemented. The phased approach may allow for improvements to be made during the implementation.
- Celebrate. This can be the most important step. The company has just completed a major project; the celebration recognizes this and clearly demonstrates the importance of the project to the organization.
- Improve continually. The organization can only absorb a limited amount of change during a finite time period. Change is an on-going process; successful companies understand this and encourage their employees to use the system to continue to improve.

2.9.6 Reasons of Implementation Failures

Implementing a new ERP system does not always guarantee successful results. Very few ERP implementation projects will result in success the first time, while others

will be total failures. According to Kapp e al. (2001), “The real reason ERP implementations fail is because employees resist the new ERP software rather than embrace it”. Also, the success and failure of implementing a new ERP system does not depend on the quality of hardware and software of an ERP system, but rather in education and training. “Success is achieved when organizations take the time to develop a training and education plan prior to beginning the ERP implementation” (Kapp et al., 2001). Jacobs and Whybark (2000; cited in Thao, 2002) stated that an organization must solve management problems and get the relationships between functions sorted out before it can implement the new system.

Another major reason for ERP system implementation failures is seen as the possibility of selecting the wrong ERP system choice to begin with. ERP projects have reported a high failure rate even jeopardizing the operations of the implementing organization. Hong and Kim (2002; cited in Kenaroglu, 2004) found that organizational fit of ERP played a major role in ERP implementation success.

Langenwalter (2000) claims that the percentage of ERP implementations that can be classified as ‘‘failures’’ ranges from 40% to 60% or higher. Ptak (1999) defines failure as an implementation that does not achieve the identified goals in the project approval phase and finds that failure rates are in the range of 60–90%.The reasons for failure can be placed into 10 categories as listed below (Davenport (1998), Davis and Wilder (1998), Langenwalter (2000), McKaskey and Okrent (1999), Minahan (1998), Oden et al. (1993), Ptak and Schragenheim (2000), Volkoff et al. (1999); Cited in Umble et al. (2003)).

1. Strategic goals are not clearly defined.
2. Top management is not committed to the system.
3. Implementation project is poor.
4. The organization is not committed to change.
5. A great implementation team is not selected.
6. Inadequate education and training results in users that are unable to satisfactorily run the system.

7. Data accuracy is not ensured.

8. Performance measures are not adapted to ensure that the organization changes.

9. Multi-site issues are not properly resolved.

10. Technical difficulties can lead to implementation failures.

2.9.7 Implementation Analysis

Nolan model is used to analyze the level of IT maturity both before and after the implementation of ERP. The Nolan model offers a framework in which different stages of IT maturity can be discussed. Nolan characterizes each stage in terms of slack and control. The four stages are (Nolan, 1979; Reynolds, 1992):

Initiation; the computer is placed in the organization. Applications are the replacement of existing manual systems (low slack) and are paid for out of a discretionary budget (low control). In this stage, the focus is on functional cost-reduction applications.

Contagion; a period of rapid and controlled growth in the number and kinds of information system applications developed. In order to nurture widespread use of computer applications in the firm, slack is high. Control remains low in order to promote extensive experimentation with applications in multiple functional areas.

Control; top management gains control over information system resources by implementing formal control processes and standards that stifle nearly all new information system projects. Management actions aim to control and reduce slack.

Integration; the use of information resources increases rapidly, providing new benefits and supporting the overall business strategy. The responsibility for operating the systems is transferred to the users. Conventional data processing activities are tightly controlled.

Nolan has modified his curve several times, due to technical developments and a better insight into computer budgeting. The central idea, however, has remained the same and so the focus remains on the four stages detailed earlier. Nolan's approach

can be used to indicate the transition from one stage to the other (Figure 2.7). After implementing ERP, the level of IT maturity is expected to increase (Voordijk et al., 2003).

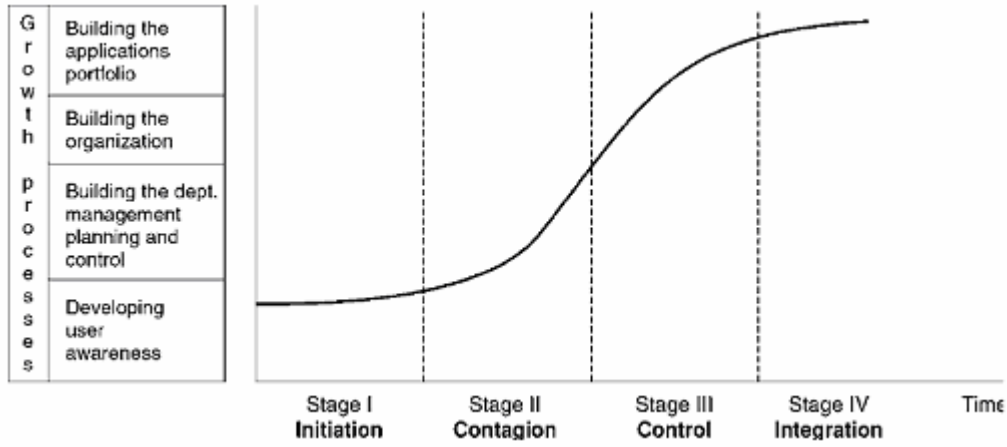

Figure 2.7 The Nolan growth curve

2.10 Cost of ERP Systems

"Cost is a major component of information technology in business but competitive advantage is the long-term benefit to be derived" as stated by Niebiesczanski (1994; cited in Steyn, 2004). Implementation of an ERP system is an extensive, lengthy and costly process, typically measured in millions of dollars. The investment is both in the software itself and in related services such as consulting, training and system integration (Parr et al., 1999).

Besides the software cost, there are other hidden costs which most organizations fail to realize. These other hidden costs are: integration, data conversion, testing, documentation, training, and consulting fees (Mello, 2002). According to Kapp et al. (2001), the cost of implementing an ERP system ranges from three times to ten times the actual cost of the software. The Meta Group did a survey of 63 different companies and found that the average total cost of ownership for an ERP system was $15 million including software cost, staff time, consulting, and hardware cost (Mello, 2002).

Mabert et al. (1999; cited in Gencel, 2003) performed a survey study to determine

the extent of package Enterprise Resource Planning system implementation. The cost composition of a typical ERP implementation occurs as:

- Software cost (acquisition of ERP package): 30%
- Hardware cost (servers, networking etc.): 18%
- Consulting (during implementation): 25%
- Training (project members and end users): 10%
- Implementation Team (for full time and part time participation): 14 %
- Other: 3.3 %

Although it has been estimated that the payback period for an ERP system typically ranges from one to three years (Buchanan et al., 2000; cited in Umble et al., 2003), the evidence is mixed. Meta Group surveyed 63 companies— ranging in size from $12 million to $43 billion in corporate revenue—to quantify the payback firms realized from their ERP investments. The data indicated that the average implementation cost $10.6 million and took 23 months to complete. In addition, an average of $2.1 million was spent on maintenance over a two-year period. Ultimately, their research indicated that companies showed an average ROI (Return on Investment) loss of $1.5 million over a six-year period (Stein, 1999).

2.11 Benefits of ERP

ERP is a helpful solution for better Project Management. ERP allows automatic introduction of latest technologies like Electronic Fund Transfer (EFT), Electronic Data Interchange (EDI), Internet, Intranet, Video conferencing, E-Commerce, Customer Relationship Management (CRM) etc. ERP facilitate eliminating many business problems like material shortages, productivity, enhancements, customer service, cash management, inventory problems, quality problems, prompt delivery, etc. ERP may not only address the current requirements of the company but also provide the opportunity of continually improving and refining business processes (Gencel, 2003).

ERP systems permit companies to implement fully integrated systems to replace their legacy systems, which are difficult to maintain because of their age, size, mission-critical status, and frequent lack of documentation. ERP systems are beneficial because they are integrated instead of fragmented, embed allegedly best business practices within software routines, and provide organizational members with direct access to real-time information (Ross, 1999).

According to Umble et al. (2003), ERP provides two major benefits that do not exist in non-integrated departmental systems: (1) a unified enterprise view of the business that encompasses all functions and departments; and (2) an enterprise database where all business transactions are entered, recorded, processed, monitored, and reported.

As Gencel (2003) mentions, the benefits accruing to any business enterprise on account of implementing are unlimited.

- Gives Accounts Payable personnel increased control of invoicing and payment processing and thereby boosting their productivity and eliminating their reliance on computer personnel for these operations,
- Reduce paper documents by providing on-line formats for quickly entering and retrieving information, Improves timeliness of information by permitting, posting daily instead of monthly,
- Greater accuracy of information with detailed content, better presentation, fully satisfactory for the Auditors,
- Improved Cost Control,
- Faster response and follow up on customers,
- More efficient cash collection, say, material reduction in delay in payments by customers,
- Better monitoring and quicker resolution of queries,
- Enables quick response to change in business operations and market conditions,
- Helps to achieve competitive advantage by improving its business process,

- Improves supply-demand linkage with remote locations and branches in different countries,
- Provides a unified customer database usable by all applications,
- Improves International operations by supporting a variety of tax structures, invoicing schemes, multiple currencies, multiple period accounting and languages,
- Improves information access and management throughout the enterprise,
- Provides solution for problems like Y2K and Single Monitory Unit (SMU) or Euro Currency.

Benco (2004) states that IT investments like ERP systems are expected to do more than add value to the firm by reducing costs and/or increasing revenues; they are expected to create competitive advantage – temporary competitive advantage at the least but, preferably, sustained competitive advantage.

In their study, Lee et al. (2004) indicates the difference on processing particular tasks in ERP and non-ERP system as listed in Table 2.5 below, in order to emphasize the time savings gained with ERP system.

Table 2.5 Additional changes in duration by ERP (Lee et al., 2004)

		Duration (h)	
Node	Tasks	Non-ERP	ERP
21	Approvals received	1	0
33	Obtain approvals for RFQ	4	2
37	RFQ ready and issue: Transmit RFQ to prequalified vendors	4	0
42	Purchase award recommendation	4	1
48	Approval obtained	1	0
49	Issue verbal award of purchase order (PO)	1	0
50	Revise specifications of PO; obtain approval of revised specifications	12	2
54	PO prepared	2	0
55	Obtain approval signatures for PO	8	0
66	Vendor prepares and submits invoice	16	0
68	Prepare overage/shortage/damage report	1	0
72	Date stamps invoice and files all documents	2	0
79	Obtain invoice approval	4	0
80	Prepare check request	2	Eliminated
81	Voucher prepared	4	Eliminated
83	Review and approve	8	1
84	Signature obtained	4	Eliminated
85	Invoice cancelled and all registers updated	2	0

2.12 ERP Applications in Various Industries

Although ERP software providers are seeking for new markets in order to broaden their business range, most providers are specialized on particular industries to maintain their competitiveness in the market, such as SAP in Chemical and Pharmaceuticals, Oracle in Energy and Telecommunications (Kenaroglu, 2004), and SSA Baan (former BaaN) in Aerospace and Defense industries. Also certain packages are regarded as having an exceptional functionality in some of their modules such as Human Resources module of PeopleSoft (Kenaroglu, 2004).

There are ERP implementations over several different industries. Examples vary from manufacturing, which is one of the major implementation areas of ERP system, to education. Many universities are adopting ERP systems worldwide, including 21 in Australia (Beekhuyzen et al. 2001; cited in Beekhuyzen, 2001). Table 2.6 shows the industries that employ ERP systems (Gartner, 2007).

Also, SAP (2007c), which is the biggest ERP provider in the world, declares its ERP business solutions per industries as Aerospace & Defense, Automotive, Banking, Chemicals, Consumer Products, Defense & Security, Engineering - Construction & Operations, Healthcare, High Tech, Higher Education & Research, Industrial Machinery & Components, Insurance, Life Sciences, Logistics Service Providers, Media, Mill Products, Mining, Oil & Gas, Postal Services, Professional Services, Public Sector, Railways, Retail, Telecommunications, Utilities, and Wholesale Distribution. Construction industry applications of ERP systems will be explained and discussed in Chapter 3 of this study.

Table 2.6 Industries that employ ERP systems (Gartner, 2007)

Industry	Area	Industry	Area
Education	Higher Education Systems	Media	Consumer–Facing Search
	K–12 Education Systems		Content Delivery
	Education Regulations		Digital Media Distribution
	Education Policy		Media Business Models
Financial	Banking		Content Protection
	Financial Services Business Strategies		Digital Home
	Financial Services Marketplace		Digital Media Marketing and Advertising
	Insurance		Digital Rights Management
	Investment Services		Media Asset Management
	Financial Services Systems		Enterprise Content Management
Government	Consolidated Service Delivery		Media Devices
	Citizen–Centric Government		Digital Consumer Technologies
	Critical Infrastructure Protection		Media Services
	Government Procurement		Rich Media
	Shared Services		Search and Information Access
	Government Marketplace		Satellite Services
	Government Processes		Web Content Management
	Government Workplace Regulations		Internet Access Services
	Government Applications		Media Regulations
	Government Intervention and Sponsorship in IT Industry		Media Business Strategies
	National Security and IT	Retail	IDRP
Healthcare Providers	Clinical Care Protocols and Workflow		Merchandising
	Controlled Medical Vocabularies		Retail Business Models
	Healthcare Provider Systems		Store Operations
	Information Life Cycle Management		Customer Relationship Management
	Natural Language Processing		Radio Frequency Identification
	Radio Frequency Identification		Pricing Strategies
	Bar–Code Labeling		Retail Systems
	Healthcare Provider Business Strategies		Retail Business Strategies
	Healthcare Provider Marketplace		Retail Marketplace
	Rules–Based Technologies	Energy & Utilities	Broadband over Power Line
	Privacy Regulations		Geographic Information Systems
Manufac-turing	Automotive Manufacturing		Energy and Utilities Business Optimization
	Consumer Goods Manufacturing		Energy and Utilities Marketplace
	Electronic Design Automation Software		Energy and Utilities Regulations
	Life Sciences Manufacturing		Energy and Utilities Systems
	Mechanical CAD, CAM and CAE Software		
	Scientific and Statistical Software		
	Manufacturing Marketplace		
	Manufacturing Regulations		
	Manufacturing Systems		
	Manufacturing Competitive Strategies		

2.13 ERP Market

Since early 1990's, the ERP software market has been and continues to be one of the fastest growing segments of the information technology industry with growth rates averaging from 30% to 40% per year (Verville and Haligten, 2003; cited in Kenaroglu, 2004).

The world's largest ERP providers include SAP, Oracle, PeopleSoft, and J. D. Edwards, which has merged with PeopleSoft in 2003. SAP R/3 is the most popular system installed across the world (O'Conner and Dodd, 1999; Jacobs and Whybark 2000; cited in Shi and Halpin, 2003).

With worldwide sales of ERP software estimated to exceed US $22 Billion by the year 2001, packaged applications would represent a significant portion of most IT portfolios (Meta Group, 1998; cited in Kenaroglu, 2004). However, it did not happen due to economical crisis in 2001 and its aspects in following years all over the world, and market volume reached $5.5 billion. In 2002, worldwide ERP new license software revenue totaled $5 billion, down from $5.5 billion in 2001. (Gencel, 2003). Table 2.7 shows market shares of top 5 worldwide ERP software applications.

Table 2.7 Market shares of Top 5 Worldwide ERP Software Applications (Gartner, 2003)

Company	2002 Market Share (%)	2001 Market Share (%)
SAP AG	25.1	24.7
Oracle	7.0	7.9
PeopleSoft	6.5	7.6
SAGE	5.4	4.6
Microsoft Business Solutions	4.9	4.6
Others	51.1	50.3
Total Market Share	100.0	100.0

A recent press release by AMR Research reported the global ERP market increased 14% in 2004 to US $25 billion for the vendors of such software (Reilly, 2005). ERP adoption continues to grow globally, despite the difficulties and risk encountered by organizations when they adopt and implement these systems (Markus et al., 2000; Nahar and Savolainen, 2000; cited in Ifinedo and Nahar, 2006).

2.13.1 Foreign ERP Software Providers (Worldwide)

Table 2.8 lists the major worldwide ERP software providers.

Table 2.8 Major Worldwide ERP Providers (Adapted from Bakry and Bakry, 2005)

ERP Provider	Establishment date / Country	Web link
SAP AG	1972 – Germany.	www.sap.com
Oracle	1977 – USA.	www.oracle.com
PeopleSoft	1987 – USA. Merged with Oracle in December 2004.	www.oracle .com
JD Edwards	1977 – USA. Merged with PeopleSoft in June 2003.	www.oracle.com
SSA Baan	SSA Global Technologies ceased to name the product as SSA Baan in 2004. Owned by Infor Global Solutions since 2006.	www.infor.com
Baan	1978 – Netherlands. – Sold to SSA in June 2003.	www.ssaglobal.com

Below is the brief information in regards to SAP and Oracle, which are the biggest two ERP software providers in the world today.

2.13.1.1 SAP

SAP was founded in 1972 as Systemanalyse und Programmentwicklung by five former IBM engineers in Mannheim, Germany (Dietmar Hopp, Hasso Plattner, Klaus Tschira, Claus Wellenreuther and Hans-Werner Hector). The acronym was later changed to stand for Systeme, Anwendungen und Produkte in der Datenverarbeitung ("Systems, Applications And Products in Data Processing"), in 1976 was founded SAP GmbH, the next year its headquarter was moved to Walldorf, and since 2005, the company's official name is just SAP AG. (Wikipedia, 2007c)

SAP aims to provide systems that enable companies to optimize supply chains, strengthen customer relationships, and make more accurate management decisions. SAP is the recognized leader in providing collaborative business solutions for all types of industries and for every major market. SAP is the largest inter-enterprise software company, and the third-largest independent software supplier overall (Gencel, 2003). The company employs more than 38,400 people in more than 50

countries, and serves more than 36,200 customers worldwide. (SAP, 2007b)

The company's main product is MySAP ERP. The name of its predecessor, SAP R/3 gives a clue to its functionality: the "R" stands for real-time data processing and the number 3 relates to a 3-tier architecture: database, application server and client (SAPgui, which is graphical user interface allows a user to access SAP functionality in SAP applications). R/2, which ran on a mainframe architecture, was the first SAP version (Wikipedia, 2007c).

The company also offers a new technology platform, named SAP NetWeaver. While its original products are typically used by Fortune 500 companies, SAP is now also actively targeting small and medium sized enterprises (SME) with its SAP Business One and SAP All-in-One. (Wikipedia, 2007c).

SAP is the world's most used ERP system and the most information and data analysis studies has been done on the SAP ERP system adoption and performance. All SAP projects are implemented using a standardized methodology known as ASAP (Steyn, 2004).

2.13.1.2 Oracle

Oracle is the world's second largest software company and the leading supplier of software for enterprise information management. The company offers its database, tools and applications products, along with related consulting, education, and support services (Gencel, 2003). Lawrence J. Ellison founded Oracle in 1977 under the name Software Development Laboratories. In 1979 SDL changed its name to Relational Software, Inc. (RSI). In 1983, RSI was renamed Oracle Systems to more closely align itself with its flagship product Oracle Database with Robert Miner as senior programmer. Oracle has offices in more than 145 countries around the world. As of 2005, it employed more than 50,000 people worldwide. In December 2004, Oracle announced that it has signed an agreement to acquire PeopleSoft for $26.50 per share (approximately $10.3 billion), which added significant value to its entity (Wikipedia, 2007d).

PeopleSoft started its operations in 1987 to design client-server applications. In 1988, the first product PeopleSoft HRMS for Human resources market was released. In July 2003, PeopleSoft Inc. had completed acquisition of J.D. Edwards & Company, making PeopleSoft the second largest enterprise applications software company in the world at the time (Gencel, 2003). Acquiring PeopleSoft, now Oracle has become the second largest enterprise applications software company in the world.

J.D. Edwards was founded in 1977 by John Thompson, Dan Gregory and Ed McVaney. The company initially created accounting software for IBM minicomputers. In 2003, J.D. Edwards was purchased by PeopleSoft and OneWorld was renamed EnterpriseOne. After Oracle purchased PeopleSoft in 2004, Oracle continues to support J.D. Edwards EnterpriseOne and J.D. Edwards World. A new release of J.D. Edwards World has been announced for 2007 (PeopleSoft, 2007).

2.13.2 Domestic ERP Software Providers

Although major ERP vendors work all over the world, there are also domestic ERP providers in particular areas.

2.13.2.1 Domestic ERP Use

In certain economies, companies may prefer to implement a business solution system which is provided by a domestic software vendor because its product perfectly complies with local business conditions. In their study, Wu and Wand (2003) indicated that 42 percent of the Top-1000 companies implemented foreign ERP packages, and 58 percent implemented domestic ERP packages. The market share for each vendor is shown in Figure 2.8. The Tiptop, Oracle, and SAP are the top three ERP packages implemented and own more than 50 percent of the market share in Taiwan.

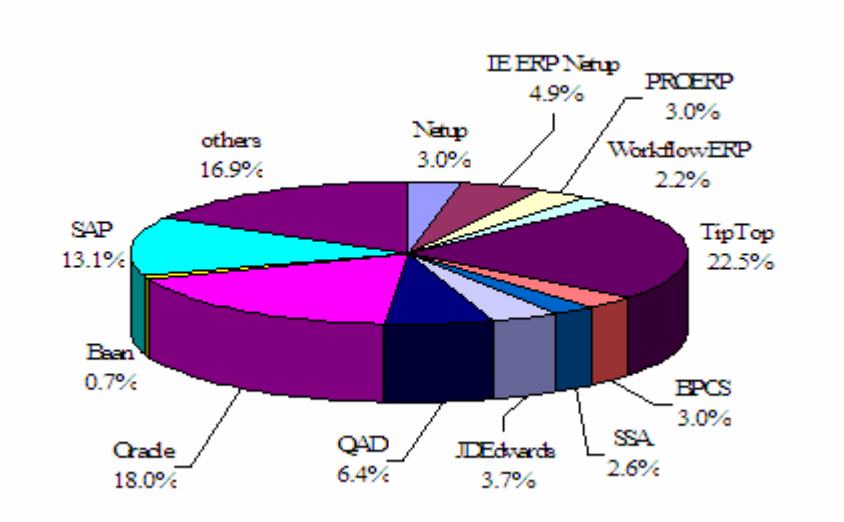

Figure 2.8 Market share for each ERP vendor among top-1000 firms in Taiwan

2.13.2.2 Domestic ERP Providers in Turkey

There are some software companies developing ERP products in Turkey. They usually work for a certain organization and provide an ERP system for their business. There are also some large scale organizations developing their in-house ERP systems. However, none of these endeavors has obtained significant results to compete with the other vendors in the world.

Worldwide consulting companies are marketing well-known ERP products in the Turkish industries. Many companies and organizations, especially international organizations, have implemented a world-brand ERP system into their business in Turkey.

In construction sector of Turkey, Yapitasi Information Technologies (Yapitasi, 2007) and Avinal Software – Construction Consulting Company provide their own ERP systems with certain modules of construction business (Avinal, 2007).

2.14 Future of ERP

In the later part of the 20th century, companies expected enterprise technologies to provide the ultimate in supply chain capabilities. Enterprises are starting to transform themselves from vertically integrated organizations focused on optimizing internal enterprise functions to more-agile, core-competency-based entities that strive to

position the enterprise optimally within the supply chain and the value network (Gencel, 2003).

According to Boyle (2000; cited in Thao, 2002), the ERP system continues to grow and is currently linked with the Web and E-commerce applications, as well as beginning to use web browsers as the graphical user interface. Furthermore, the future of ERP is being shaped by the following four trends: a) improving integration and flexibility, b) inclusion of e-business applications, c) wider range of customers, and d) adapting to the Internet (Mello, 2002). The idea behind integration and flexibility was to create an application that would easily interact with other applications of different vendors. In the past people did not realize the importance of sharing information, but now information sharing has become great valuable to all organizations.

The ERP II vision addresses the future by focusing on deep industry domain expertise and inter-enterprise, rather than just enterprise business processes (Bond, 2000; cited in Gencel, 2003).

3. SUITABILITY OF ERP SYSTEMS IN CONSTRUCTION BUSINESS

Chapter Three discusses the nature of construction industry, its needs and unique conditions, current and possible difficulties in ERP applications in construction business, and suitability evaluations of ERP system applications for construction parties.

3.1 Nature of Construction Industry

Construction is the process of transforming materials and permanent equipment into a finished facility (Peurifoy et al., 1996). Compared with other industries, typically the manufacturing industry, the unique characteristics of the construction industry have been widely recognized (Tucker, 1988; Oglesby, 1990; cited in Shi and Halpin, 2003).

The construction industry is a highly fragmented industry. It needs to communicate on a large scale with other related businesses such as material and equipment suppliers, vendors, subcontractors and clients (Ahmed et al., 2003). Its segmented phases and various participants make the management of construction projects problematic. (Ryoo et al., 2007)

Although construction industry shares some similarities with manufacturing industry, it mostly produces customized one time products. Some of these projects may last for years. (Tatari et al., 2004)

The uniqueness of the industry has prevented the direct implementation of many methods and concepts developed in the manufacturing industry, such as the mass production method. Such uniqueness forces researchers in the construction community to develop their own science base for the sustainability of this major industry (Shi and Halpin, 2003).

3.1.1 Participants of Construction Business and Operation

The construction process involves many participants in the management of the construction contract and operations. Project management requires a coordinated team work within all project participants which includes monitoring a constantly evolving project, documenting project correspondence and field changes, managing the coordination between suppliers and the field operations, reviewing contractor and subcontractor performance, testing and inspecting, administering project schedule, and projecting costs and cash flow. The team members and the duties they perform are as following:

Owner (O); makes the initial request for a project that will be designed by Architect/Engineer. Owner may refer to an individual, a company or a public institution. Owner provides the funding for the project and is responsible of the timely release of funding.

Architect / Engineer (A/E); prepares complete design of the facility in compliance with the code, standards and local ordinances. A/E provides construction documents to the general contractor including complete set of drawings, all technical details and project specifications; reviews contract submittals, shop drawings, samples, schedules and correspondence. A/E also may be representing the owner as performing the tasks and duties of Owner's Representative.

Owner's Representative (O/R); represents the owner in every level of relationship with all project participants. O/R assesses project quality and compliance with construction documents; reviews contract progress and schedule with contractor's invoices and costs, and informs and advises the owner to release the progress payment; processes and documents required contract modifications; assesses project status for substantial completion; certifies project completion and fulfillment of contract documents.

General Contractor (G/C); manages the whole project and is responsible for the successful completion of the project on time, within the budget and assuring the quality requirements. G/C procures the necessary materials, equipment, and components by producing in in-house facilities or purchasing from the vendors and suppliers; provides the manpower by employing and/or supervising the necessary

personnel and subcontractors. G/C coordinates the work of all trades, review and inspection by governmental agencies; administers project costs, invoices, and subcontractor disbursements; documents contract modifications and site conditions; obtains permits and field inspections and pays incidental fees as specified by the contract; issues warranties and guarantees as required by the contract.

Subcontractors (S/C); work for the G/C and perform their job per the contract. G/C subcontracts particular portion of the work to a subcontractor. Subcontract requires a subcontractor to perform the work in compliance with the contract documents.

Suppliers and Vendors (S/V); provide materials and services to G/C and S/Cs in compliance with the material specifications.

District's Representative (D/R); includes governmental agencies involved in construction work authorization and access issues; provides access to and availability of the project site; contracts for special inspections and required testing; reviews contractor's use of the site and protection of the district's property. D/R issues the certificate of occupancy for the facilities.

The physical relationships between the participants of the project are deliberately described in construction documents. All participants are required to perform their duties per construction documents.

Construction operation requires comprehensive coordination between all parties. Shi and Halpin (2003) described internal and external resources of a construction enterprise in order to determine the strategy for both ongoing and potential projects. Figure 3.1 shows the diagram of construction enterprise operation and its related parties who are in relation or possibly work together accordingly as below:

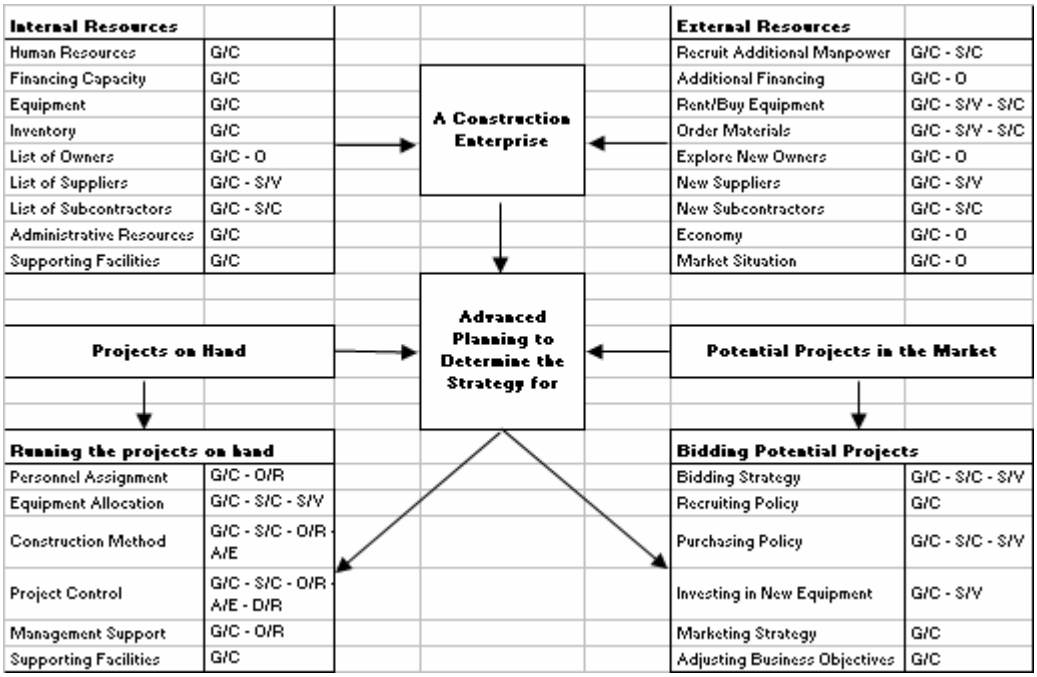

Figure 3.1 Construction enterprise operation and respective parties (Adapted from Shi and Halpin, 2003)

3.2 ERP Systems in Construction

There is a common terminological confusion for the terms “ERP system” and “construction ERP system”. Although some researchers recognize construction ERP systems as separate and different than ERP systems, this study describes construction ERP system as following:

Construction ERP system is an ERP system which provides comprehensive solutions to construction business’ industry-specific problems and needs. Readers should consider this description while interpreting the information provided with this study.

3.2.1 Introduction to ERP in Construction

With the development of new technologies such as the drawing tool, Internet, and wireless instruments, many companies now consider technological improvements an essential part of their long-term competitive strategy, and consequently try to apply these technologies. Computer technology has brought about many benefits in helping the construction industry meet increasingly complex challenges (Paulson, 1995). It

has achieved a wide range of successful applications at the project level such as engineering design, project estimating, scheduling, planning and control, and integrated project management. Since its applications in the construction business are still very much limited to areas such as accounting, costing, and financing functions, research is essential in exploring a wider range of usage of computers to improve the efficiency of construction business operations and management (Lee et al., 2004).

The need for business system integration has led many large manufacturing companies in America to invest heavily in ERP systems. With these large investments come high expectations regarding system performance and associated benefits to the corporation. Many executives in these companies expect ERP systems to integrate nearly all facets of their business, including the acquisition of new or expanded capital facilities. This has raised many concerns within both owner engineering/project management organizations and contractor/supplier organizations. Accordingly, it is valuable to assess the impact (or anticipated impact) that these systems will have on the facility engineering and construction delivery processes (O'Connor and Dodd, 2000).

The construction industry has some uniqueness that should be taken into consideration by ERP vendors (Lee et al., 2004). Since existing ERP systems are primarily developed for the manufacturing industry, they can hardly meet the needs of the construction industry (Shi and Halpin, 2003).

3.2.2 Objectives of ERP in Construction

Today, an ERP system is the information technology (IT) backbone of the corporate infrastructure (Bechler, 1997). It provides an integrated multifunctional, multisite, and multinational business management tool (Thompson, 1996; Gibson and Holland, 1999; Tinham, 1999; cited in Shi and Halpin, 2003).

ERP systems are being used by construction companies to improve responsiveness in relation to customers, strengthen supply chain partnerships, enhance organizational flexibility, improve decision making capabilities and reduce project completion time and lower costs. These information systems are designed to integrate and partially automate many of the company's business processes such as human resources,

financial management, manufacturing, procurement, construction, operations and maintenance. The goal of ERP is to support one time entry of information at the point where it is created and to make it available to all the participants within the organization (Ahmed et al., 2003).

3.2.3 Resource Planning and Material Management in Construction

Procurement process for construction industry is the most similar process with the same process of manufacturing industry among all processes. Since many intermediate steps of the procedure overlap, material management applications are the most common construction ERP application examples considering their practical applicability and transmission convenience from manufacturing business language to construction business language.

Compared with a manufacturer who has production facilities (e.g., plant, assembly line, etc.), a construction company has different resources since several parties including the owner, designer, contractor, subcontractor(s), and supplier(s) are involved in delivering the facility (Peurifoy et al. 1996).

Construction processes can be partitioned into repetitive sequences that more efficiently use resources such as equipment, labor, and materials. This repetitive nature of modern construction operations helps simulation to study the repetitive process under different variables with the goal of increasing productivity. The implementation of ERP in the material management systems (MMS) can provide substantial benefits. (Lee et al., 2004).

The material management process combines and integrates the individual functions of material requirements planning, material takeoff, vendor evaluation and selection, purchasing, expedition, shipping, material receiving, and inventory, material distribution, and even accounting functions (Bell and Stukhart, 1987). Those engaged in this complex process has to be coordinated and communicated effectively.

Many construction firms have got computer base material management systems (MMS), which stores, sort, combine and print data files pertaining to materials requisition, purchasing, vendor evaluation and warehouse inventories (Bell and Stukhart, 1987). The purpose is to integrate MMS with external computer systems to

perform functions related to design, project scheduling and accounting, improving cost and document processing cycle time by the use of information technology systems. There are some implemented information technology systems such as DBMS (data base management system) and EDI (Electronic data interchange) (Elzarka and Bell, 1995). **DBMS** permits the user to organize, store and manage all electronic data relating to a major activity or area of interest, while allowing users to enter and store data for once and utilized by multiple users and application; and **EDI** is a direct computer application exchange of business data in standard format, thus eliminating the need for the reentering the information.

In a study made by Lee et al. (2002), a simulation model to implement ERP in the material management is created. They stated in their study that an ERP system shortens procurement cycle by 80% approximately, through automating most of the repeating transactions, and by reducing manpower to perform the tasks.

3.2.4 Construction ERP Models

Below is the conceptual construction ERP models proposed by Shi and Halpin (2003); and by Ryoo et al. (2007).

3.2.4.1 3-Tier Model by Shi and Halpin

Shi and Halpin (2003) presented a 3-Tier architecture model for construction ERP implementation as illustrated in Figure 3.2, and described the functions in each tier as following:

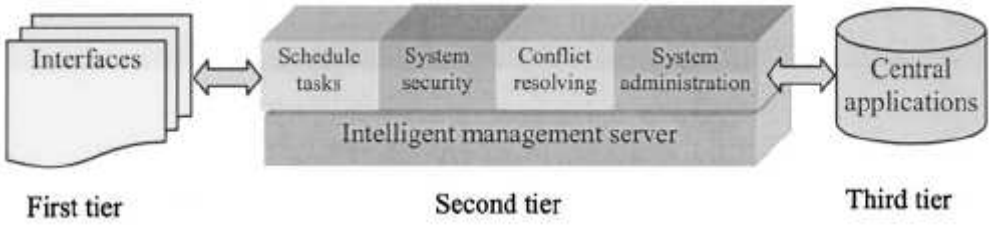

Figure 3.2 3-Tier architecture of construction ERP (Shi and Halpin, 2003)

First tier (User Interfaces - Clients) presents interfaces to various users across a construction enterprise. System users are classified per their office functions, such as

payroll, accounting and financing, human resources, purchasing, equipment division, project management (operations), estimating and engineering, or corporate-level management.

Second tier (Management Server) provides system administration and maintains central intelligence for facilitating clients and applications. The second tier (management server) is the bridge between the first tier (end users) and the third tier (applications). When a request is raised in the system, a corresponding process model will be identified and executed by the management server. Jacob and Whybark (2000; cited in Shi and Halpin, 2003) stated that SAP R/3 contains more than 8,000 standard processes based on the best industry / business practices. Also, in case of a conflict between requests, it will be solved by the management server while being supported by intelligent agents or responsible managers.

The third tier (Applications) is the central database and applications server. The central database contains cost data, project data, equipment information, and any other corporate-level information. Shi and Halpin (2003) organized construction applications in three groups as following:

- Corporate-level applications, which plan corporate resources, determine bidding strategy for new projects, marketing strategy, operation and business strategy of the enterprise, and provide corporate management tools.
- Project-level applications, which serve for cost estimating, scheduling, planning, resources management, progress reporting and control, and quality assurance.
- Back-office applications, which include human resources, purchasing, warehousing, accounting, financing, and equipment management.

3.2.4.2 4-Tier Model by Ryoo et al. (2007)

Ryoo et al. (2007) presented a 4-Tier architecture model for integration of Enterprise Resource Planning (ERP) and Project Management System (PMS). They pointed out that the existing 3-Tier based ERP and PMS need additional interfaces in order to handle functional dissimilarity between ERP and PMS. Also, integration with industry-specific programs in design and construction -such as scheduling,

estimating, document and contract management- is necessary. Figure 3.3 shows proposed 4-Tier architecture model, and the third tier, Application Programming Interface (API), is inserted in order to link external systems, programs, or databases as needed.

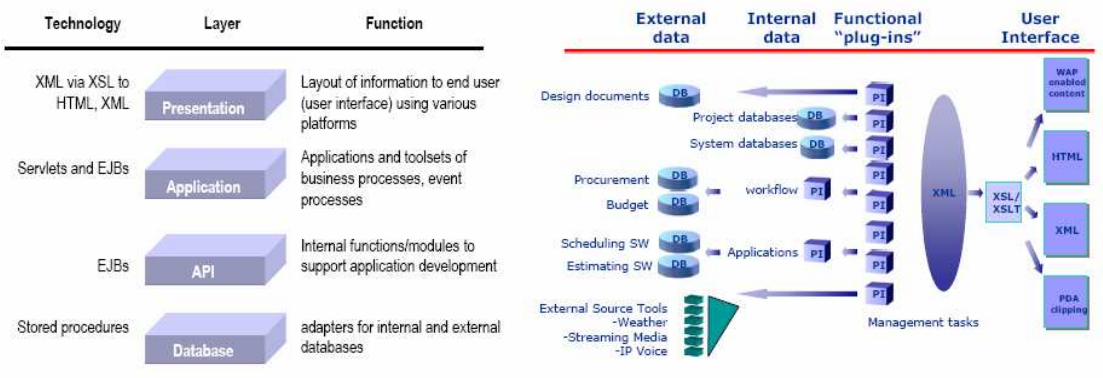

Figure 3.3 4-Tier architecture and functional integration (Ryoo et al., 2007)

According to the model shown in Figure 3.3, functional “plug-ins”, which store different contents and also called componentized modules, can be divided into two major types as service modules and utilities modules. Service modules refer to the actual application in the construction industry such as contracting, scheduling, and estimating; and utilities modules refer to user management and security management. Ryoo et al. (2007) stated that different modules can be selected by users according to their specific needs.

This approach allows various types of data interchange between ERP and existing solutions and programs with minimum modification by adding a tier. It also enhances scalability, and improves robustness by adopting existing workflow (Ryoo et al., 2007).

3.2.5 ERP Software Packages in Construction

Although there is still not a complete example of a construction ERP application in the world that matches with every single need of the industry, there are some software packages available in the market. Most of the major ERP software vendors are seeking for individual ERP solutions for construction industry needs.

There are many limited-scope construction ERP applications as available software

packages allow companies and owners to implement on a certain part of their business. Also there are ERP vendors providing construction business modules in their packages. Some of them are as following:

SAP is the largest of the ERP vendors and its product "**SAP R/3**" is extremely popular among large industrial manufacturers with large capital building programs. SAP has targeted the engineering and construction (E&C) sectors as growth markets for their products and has developed unique supplements or extensions of its R/3 software to handle some of the unique needs of these sectors. The major modules of SAP R/3 are Project Systems (PS), Materials Management (MM), and Plant Maintenance (PM). PS handles many functional needs involving cost management, schedule management, subcontractor management, project documentation, and construction planning. MM handles many functional needs involving field equipment management, field materials warehouse management, subcontractor management, and procurement management. PM handles many operational needs such as those associated with facility maintenance management, facility operations, schedule management, and cost management. Many other project management needs are fulfilled by modules such as Environment, Health, and Safety (EH&S) for safety management functions and QM for quality management functions (O'Connor and Dodd, 2000).

mySAP is the successor product to SAP R/3. In addition to key functional areas provided by mySAP, there are also industry-based solutions. **mySAP EC&O** (Engineering, Construction & Operations) is the specific solution for construction industry (SAP 2007d). The system contains modules such as Project Management, Financial Management, Enterprise Asset Management, Sales Process with Bill of Services, Equipment and Tools Management, and Real Estate Sales for Homebuilding. mySAP also provides additional capabilities to the users like CAD integration, internal and external collaboration via SAP Netweaver, which is a platform enabling different SAP products to work together (Anderson and Larocca, 2006), and resource-related down payments and billing.

EasyBuild is construction ERP software, which has been specifically provided by Sapphire Group for the construction industry (EasyBuild 2007). Major partners of EasyBuild are Oracle and IBM Server Proven, therefore EasyBuild is also

compatible with some other Oracle ERP modules. Modules provided by EasyBuild are as following: Contacts Management, After Sales Assisting Customer Care, Cash Book, Clients and Architect Certificate Balances, Consultants, General Ledger, House Sales, Land, Monthly Personnel, Plant, Projects, Stock of Materials, Subcontractors, Suppliers, Weekly Personnel, and System Setup.

Another construction ERP vendor is **CMiC**, which is located in Canada. Computer Methods international Corp. (CMiC) is providing specific solutions for General Contracting, Design Build, Construction Management-at-Risk, and Construction Management-at-Fee firms. CMiC currently holds 25% of market share of the US market for CM at Risk companies (CMiC 2007). Main modules of the package are Financials, Projects, Human Capital, Assets, CRM, Cost & Budget Management, Bid & Procurement Management, Site Management, Collaboration Manager, Imaging, Workflow, Business Intelligence, and Mobile.

IFS (Industry-Focused Software Solutions) is the one of the leading construction ERP providers in the world, and its headquarters is located in Sweden. IFS provides business-specific ERP solutions for many industries, including construction industry (IFS 2007). Its construction business solutions are grouped as Construction – Building & Civil Engineering, Engineering Contracting – EPCI (Engineering, Procurement, Construction and Installation) Contractors, Shipbuilding – Commercial, and Service Providers – Service and Maintenance Management, as they are based on the type of the business operations. Basic key functions are Cost Control; Valuations, Applications for Payment & Retentions; Project Planning and Resource Management; Contracts, Sub Contracts, Taxation and CIS; Change Management; Document Management; Core financials & Procurement; Human Resources and Training; Payroll, and ‘Time & Attendance’; Consolidated Reporting (over a group of projects); and Maintenance (planned and reactive).

OPTICON is a comprehensive, integrated, modularized and user-friendly ERP System for the construction industry. It is a ready to use system, which is useful in quick implementation and thus reducing the lead-time. The implementation is modularized type and the addition modules can be linked at any time as per the customer's requirement (Opticon 2007). Some modules are Planning and Design, Rate Analysis and SOR, Tenders and bidders, Measurement Book, Scheduling and

Execution, Reports, Purchase and Inventory, Sales and Marketing, Accounts, HR and Admin, Contracts, and Documents.

The above referenced samples are not representing the all available construction ERP vendors, but are the major ones. There are some other construction ERP vendors in the market, especially local vendors. Construction ERP solutions above mentioned provides many significant solutions to construction business.

3.2.6 Benefits of ERP Applications in Construction

Enterprise systems are rich in terms of functionality and their potential benefits to adopting organizations (Markus and Tanis, 2000). According to Ahmed et al. (2003), benefits of implementing the ERP Systems are providing an integrated working environment, enabling automation, availability of information from the field level to the management level, flexibility and facility to standardize process or to accommodate changes, world-wide business globalization, balancing the manpower, procedure and technology changes across all areas, and controlling practices through the project life cycle.

Rawlins (2004) summarized the benefits of ERP in construction and mentioned three data-centered benefits associated with ERP solutions as; (1) Eliminates data latency: ERP systems update data everywhere simultaneously, so data latency (data that has been updated in one system but not yet in another) is impossible; (2) Reduces data redundancy: A fully integrated system prevents data duplication in disparate systems; (3) Decreases data entry duplication: Integrated systems use a single data source. Without a single data source, manual intervention is required to rectify failed validations when synchronizing data.

Rawlins (2004) also stated that the other advantages to implementing a Construction ERP include the ability to:

- Increase profit margins by eliminating unnecessary SG&A (Selling, General and Administrative) expenses,
- Sort through transactions on any given project by date, vendor, contractor, or project manager,

- Manage and monitor subcontractors more closely,
- Receive change order approval in minutes, instead of days,
- Produce a detailed and accurate bill, with full documentation, at the press of a button,
- Forecast annual results more accurately,
- Deliver more precise bids faster than competitors who may rely on labor-intensive research and paperwork.

Shi and Halpin (2003) explained the main benefits of a construction ERP application as information sharing, improved transparency of management responsibilities, and improved management efficiency. They emphasized that once a piece of information is generated, it is stored in the central database, so everyone could reach with an appropriate access permit. This eliminates the traditional information maintenance method by responsible offices and interoffice data flow difficulties. They also expressed the importance of transparency of the work flow and management responsibilities. Tasks are performed one by one by following the sequence given in the system, and after one task is complete, system will move to the next. System keeps all details of all tasks during the process. They also stated that an ERP system improves management efficiency by providing timely and consistent information, and a coordinated decision-making environment.

Benefits of a construction ERP implementation may also be expressed in numbers. Dodd (1999; cited in Lee et al., 2004) analyzed the performance of construction procurement functions of SAP R/3, which is the most commonly used ERP software. The ERP system was found to be capable of shortening the procurement cycle of the MMS (Material Management System) by automating most of the repeated transactions and reducing manpower to perform the tasks. The individual task improvements of the system can increase the productivity of the materials management cycle by up to 5.2%, 18.2%, 27.8%, 13.5%, and 79.2% using application integration, internal integration, external integration, automation, and ERP system, respectively(Lee et al., 2004).

3.2.7 Risks of ERP Applications in Construction

An ERP system for construction should be able to work in the riskful environment of construction business. There is some risk in construction such as **seasonal workload fluctuation** and **lower-than-cost bids**. People working in the construction industry sometimes complain of being overloaded and of being required to work overtime when the business is good; and they worry about their job security if there is not enough work to be employed. Besides, it is common to see lower-than-cost bids when contractors really need new projects in order to keep the company operable. Such a gambling strategy has driven many contractors out of business. Poor profits were found to be the top cause responsible for construction business failures (Kangari, 1987; cited in Shi and Halpin, 2003).

Griffith et al. (1999) reported that about three quarters of the ERP projects were judged to be unsuccessful. A common problem when adopting ERP software has been the issue of **misfits**, that is the gaps between the functionality offered by the package and that required by the adopting organization (Wu and Wang, 2003). Therefore, starting with the description of the business, initial functional analysis has to be intensive and accurate. These initial analyses will lead the ERP selection team to identify the company's business-specific needs and its strengths.

An ERP system can have a **negative impact on the work practices and culture** of an organization (Allen and Kern, 2001; cited in Beekhuyzen, 2001). In order to minimize the risk of negative impact, system and the whole process need to be explained to every level of employees as necessary. Top level management's motivating behavior is very effective in order to cope with organizational culture issues and their aspects.

High implementation cost is another risk factor. The total cost of ownership (TCO) of ERP, as identified by the Meta Group (Koch et al. 1999) is averaged at $15 million per system. This cost varies depending on the size of the company, business type, global operations etc. Considering the excessive amount of the system, the construction company must have a master cash flow plan for ERP implementation. In case implementation extends, company should be capable to cover additional costs. Also, company needs strong financial structure to maintain the business until

company starts making profit utilizing the new system. **Return on investment** (ROI) period may take longer than it is anticipated, so company needs to have alternate financial resources in case of emergency.

This should be kept in mind that every improper action creates new risk of failure, so any mistake through the life-time of a construction ERP system will be a threat as ERP is based on the accuracy of data just like every other computer-based information system.

3.2.8 Case Studies

There are vast amount of case studies for ERP applications. However, there is less number of case studies in construction ERP applications. Most of construction ERP application case studies are related to non-construction part of the business implementations such as financials, accounting, and human resources.

For example, Layton Construction has implemented an ERP system into its business. The company is located in Utah, USA. Implementation consists of four major modules; financial, project accounting, subcontracting, and payroll applications. Rawlins (2004) stated that Layton Construction has gained significant benefits from the implementation.

Another example of Oilco Company, which is an industrial company in Australia, may be briefly mentioned. Oilco employs 2000 people and owns assets valued A$2 billion. The implementation cost A$70 million and extended over a 7-year period. (Parr and Shanks, 2000)

Batigroup, which is a leading Swiss engineering and construction company with annual revenues of around 730 million Euros and 3500 employees, has implemented mySAP ERP Solution and gained 28% reduction in IT costs, streamlined financial analysis and enhanced decision making, capability to work with actual market prices and historical data, and increased competitiveness in the market as technological leader (SAP, 2007d).

It is not possible to make generalizations based on the current case studies and success stories of the companies as they are all different in details. ERP

implementation is extremely comprehensive application and depends on numerous factors, so typological data is need in order for researchers to reach generalized consequences, and this will take years for the market to produce that kind of data by business applications.

3.3 Difficulties in Construction ERP Systems

Difficulties in construction ERP systems are categorized into four as following: difficulties in construction ERP studies, difficulties in using current ERP products, difficulties in information technology (IT) applications, and difficulties in implementation.

3.3.1 Difficulties in Construction ERP Studies

Although there are some construction ERP studies, case studies and surveys conducted, they are not enough yet to come up with conclusive findings. For example, Ifinedo and Nahar (2006) investigated the prioritization and evaluation of ERP systems success assessment using two organizational stakeholder groups consisting of top-level and mid-level managers in Finland and Estonia. Some of these companies use top-brand ERP products, and the others use mid-market. In this study, findings can be concluded according to markets, as in Finland and in Estonia; respondents as top-level managers and mid-level managers; or products as top-brand products and mid-market products. However, due to limited number of responses (total 62 out of 470), it is not possible to reveal general conclusions for every condition. Other than these classification factors, there may be many others such as company size, type of business specialization, sole or corporate operations, local or global operations, owned assets, in-house capabilities, level of ERP use, use of other supplementary systems etc.

Since there are many different categorizations for construction ERP products, vendors, clients, industries, almost none of the findings are completely validated. Therefore, diversity of the affecting factors should be deliberately reviewed according to the particular purpose of the research. The wide scope of ERP and the complexity of the system force researchers to narrow down into smaller pieces of the subject. Also vast number of participants and various different types of

implementations increase the diversity of the case conditions, so researchers need to set the conditions very carefully as field studies can only be conducted once. Shi and Halpin (2003) stated that a 1999 NSF (The National Science Foundation of US)-sponsored workshop realized the problems and concluded that a science base of ERP technology is not developed yet and that the ensemble of separated functional systems is untested.

3.3.2 Difficulties in Using Current ERP Products

Current ERP Products such as SAP R/3, mySAP, EasyBuild, Opticon, CMiC, and IFS are handling many functions of construction business. Most of ERP products provide certain level of satisfaction on back-office functions such as order management, financial management, warehousing, distribution, quality control, asset management, and human resources. Back office functions are basic elements of a business and are more or less same for every industry. Divergent part of construction business from the other industries is front-office functions such as site management, project management, estimating, bidding, and scheduling.

In order to evaluate the capability and efficiency of an ERP system in construction, O'Connor and Dodd (2000) conducted functional gap analyses with SAP R/3, which is the most popular ERP product, and identified satisfying and dissatisfying features of SAP R/3 in their study as following:

Satisfactory features of SAP R/3 software are system integration within materials management, procurement, fixed assets, resource planning, budgeting/availability control, project management, and asset accounting. Excluding project management and resource planning partially, all these satisfying points are belonging to back-office functions.

On the other hand, dissatisfying points of R/3 are excessive amount of accounting settlement rules, inability to forecast additional cost (which is vital to construction business), lack of work order functionality, cash flow planning deficiencies, unhandy and complicated confirmation process, and determination of percentage complete based on physical progress (which is lifeblood of scheduling).

Above and beyond satisfying and dissatisfying features of R/3, there are many

functions working deficiently. These functions are shown in Table 3.1 with their respective departments below:

Table 3.1 Deficiencies of SAP R/3 (Adopted from O'Connor and Dodd, 2000)

Deficient Function	**Respective Department**
Unit price tracking	Scheduling - Accounting
Job cost reports	Accounting
Labor cost reports and work-hour forecasting	Accounting
Change order cost tracking	Scheduling - Accounting
Work breakdown structure model	Scheduling
Project conceptual / milestone schedule	Scheduling
Detailed activity precedence network	Scheduling
Project schedule reports	Scheduling
Short interval planning	Scheduling
Purchase order development and issuance	Accounting
Monitoring of change orders, rework, and backcharges	Accounting
Management of contractor retainage	Accounting
Tracking and documenting percentage of physical completion	Scheduling - Accounting
Field warehouse inventory management	Material Management
Warehouse inventory reorder processing	Material Management

Also, below is Table 3.2 showing functions not provided by R/3:

Table 3.2 Missing Functions of SAP R/3 (Adopted from O'Connor and Dodd, 2000)

Missing Function	**Respective Department**
Existing building configurations	CAD – Engineering
Schematic facility configurations	CAD – Engineering
Detailed design configurations	CAD – Engineering
As-built configurations	CAD – Engineering
Technical specifications	Engineering
Physical interference detection	CAD – Engineering
Facility walk-through simulation	CAD – Engineering
Equipment selection and scheduling assistance	Material Management – Scheduling

O'Connor and Dodd (2000) identified 54 functions in their study; they judged 31 of them as adequately or even fully working, 15 of them are deficiently working, and 8 functions need to be added to SAP R/3. Highlighting 31 of 54 (57%) are adequate; they concluded these results as very good, considering the difficulty that

organizations encounter otherwise in integrating so many necessary functions into their businesses.

At this point, this should be discussed that SAP R/3 had provided an overall (57%) satisfaction in year 2000 because it was the most efficient tool to integrate the business. Therefore, this success was not achieved because SAP R/3 is a great construction ERP solution; the reason for the satisfaction is the need of business integration.

Although the successor product of SAP to SAP R/3, mySAP (SAP 2007d), has fixed most of the problems in regards to accounting, material management and CAD-based applications; it still needs to be improved in certain areas such as progress scheduling and change order management, in order to become a perfect tool for construction business.

In order to simplify the difficulties, it is very beneficial to underline the major difficulties as following: scheduling issues, accounting issues and integration issues.

3.3.2.1 Construction Scheduling Issues

There is a common misunderstanding of the meaning of “scheduling” in practice. Actually, scheduling is a general term for many industries. It both has a meaning of “the planning of the production or the operation (Wikipedia, 2007e)”, which refers to scheduling of construction activities, and “ensuring that an organization has sufficient staffing levels at all times (Wikipedia, 2007e)”, which refers to manpower scheduling. Although construction scheduling obviously includes material and equipment scheduling, these tasks may be performed separately. Most companies use static scheduling tools in order to put their activities in sequence. However, since these activities are not tied to each other, any changes become a problem.

As a strong demand of the construction business, changes inevitably happen. Therefore, construction scheduling needs flexible tools in order to keep the project under control, also need to see the time and cost effects of changes. This is also tremendously necessary to see the status of the project on a cost and resource loaded schedule.

Many ERP vendors show the status of the project based on financial data. This may be calculated per financial completion or progress payments received, or another alternate way according to company's decision. For example, EasyBuild shows project status as shown in Figure 3.4 below on its CVR (Cost/Value Reconciliation) report.

Although it is a powerful tool, there is still a need to project timeliness of the project in construction business as well as the cost completion. This should be emphasized that financial status usually does not explain or point out any ongoing problems of the project, so this is insufficient information on project management side of the business. As a result, a construction ERP product should utilize high-capability construction scheduling module, which allows users to make any changes on the existing schedule, follow the impacts, and figure out cost related changes accordingly. This module also needs to be in relation with project management and accounting modules so respective parties may proceed with their part of the process.

Figure 3.4 Screenshot of "Projects" module of EasyBuild (EasyBuild, 2007)

3.3.2.2 Construction Accounting Issues

Unlike other industries, construction calls for very specific data fields that typically

are not found in off-the-shelf ERP software packages from large vendors (Rawlins, 2004). Construction accounting operates some regular tasks different than the other industries, also has some additional procedures.

Construction accounting operations contain some industry-specific processes such as retainage accounting, pay-when-paid policy, subcontractor compliance and certification, productivity-based forecasting, job cost reports, change orders, rework and backcharges, and accounting standards.

General contractors (G/C) retain certain part of the payment to its subcontractors (S/C), suppliers and vendors (S/V) for project-based costs, as their payment is retained by the owner accordingly. Retainage ratio is generally within 5% to 10% as specified by contract documents, and is subject to change per contract. As a result, construction accounting applies **retainage accounting** to its transactions per contract.

General contractors (G/C) typically **pay** their parties **when** they are **paid** by the owner. This is specified in subcontracts and purchase orders as payment term. It is G/C's responsibility to receive its payments from the owner on time, and pay its S/C's payments on time accordingly, in order to main relationships for future jobs.

Subcontractor (S/C) **compliance and certifications** may affect payments schedule and percentage. For example, there are certain certifications such as DBE (Disadvantaged Business Enterprise), WBE (Women Based Enterprise) and MBE (Minority Based Enterprise) in United States of America (DBE, 2007). Certified S/Cs and S/Vs have some privileges and priorities in payments by law, in order to maintain their business. On the other hand, public projects in America require employment of certain amount of minority people such as Black (B), Asian (A), and Hispanic (H). Employment of minorities has to be shown on Canvas Reports complying with project requirements.

Job cost reports need to be prepared per project in construction business. Job cost reports reflect financial status of the project, and provide all cost information to accounting department. **Change order** entries need to be copied to accounting department so transaction process may start, and change order entries and cost changes need to be reflected on job cost reports.

Backcharges are extra costs caused by other parties. G/C may repair and/or fix the problem by itself or having S/C to do, and backcharge the cost to whom caused the extra cost.

Also, there may be difficulties in **accounting standards** such terms in different languages, currencies, availability of widely used accounting standards such as U.S. GAAP (Generally Accepted Accounting Principles) and IAS (International Accounting Standards) (SAP, 2007d).

3.3.2.3 Integration with Non-ERP Systems

Current construction ERP products may not exactly fit in the needs of a construction company. It is possible to ask vendor to customize the product accordingly, however it is limited to vendor's capability and capacity to accommodate all requests. In this case, construction companies may need to utilize supporting software products in integration with their ERP system. However, these systems can transfer and interchange data in varying degrees. Other integrated system software vendors (most are specialized on a specific type of product such as Documentum, Bentley, Autodesk, Primavera, and Microsoft) can support as necessary. O'Connor and Dodd (2000) brought up a concern for SAP R/3 integrations in their study so that the primary concern pertains to the extent to which data generated by these systems can be accessed and manipulated within the integrated R/3 framework.

Following are three examples of integration of ERP systems with non-ERP systems such as planning and scheduling tools, other industry-specific softwares, CAD-based softwares, and project management systems.

Brown and Root (contractor) globally implemented SAP R/3 in association with Halliburton, having 15,000 users and 400 physical locations (Jackson 1998; cited in O'Connor and Dodd, 1999). They combined their project management software system, IPMS (Integration Project Management System), with SAP R/3 for better handling of projects, especially large projects.

Foxboro Companies (supplier) has integrated its management system, ICIMS (Integrated Control and Information Management System), with SAP R/3 (Hodgson, 1998; cited in O'Connor and Dodd, 1999).

Another example is Intergraph (supplier) Company. Intergraph linked its engineering system (IEBOM – Intergraph Engineering Business Object Model) and information system (EIMDW – Engineering Information Management Data Warehouse) with SAP R/3 (Wallace 1998; cited in O'Connor and Dodd, 1999).

According to Rawlins (2004), as new versions of each system become available, all validation routines of the bridging must be updated and data exchange routines must be retested. This may cause some difficulties or inconvenience in further times while maintaining integrated systems.

3.3.3 Difficulties in IT Applications

Components of the ERP system are provided and installed by the ERP vendors. The vendors make sure that the customer, which is generally contractor in construction business, has compatible hardware and software configuration. The ERP vendors also provide system updates and necessary training sessions per the contract with contractor. In construction business, reaching to certain level of IT maturity, data collection, accuracy and validity contain some difficulties as mentioned below.

3.3.3.1 IT Maturity

On technological side of view, ERP implementation is an IT (Information Technology) application as this requires certain level of capacity of the system components. Nolan Analysis, as previously mentioned in Section 2.9.7, shows that construction organizations have yet to reach the first stage (initiation stage) of the Nolan Curve, as previously shown in Figure 2.16. This also proves the low level of user awareness in construction industry. The temporary nature of the organizational structure impedes a high IT maturity at the project level. (Voordijk et al., 2003) Therefore, construction ERP implementation will take longer time to increase IT maturity than the other implementations, as it is project-based business.

3.3.3.2 Data Collection Problems

In perspective of contractors, construction business produces one time non-repetitive products, and each production period has its unique conditions. In the end of each period, disparate set of data has been created. Contractors need proper tools in order

to store the data created by experience, and utilize in further jobs as necessary.

The fragmentation of construction business has also led to the fragmentation in type, quality and amount of data and information generated throughout a project's life cycle (Artuk et al., 2007). All data for the project, including contact information, specialties, resources, cost and duration data, need to be stored appropriately during the project in the system. This needs very strict initialization stage for data collection that users must be completely aware of what they are doing. Once system set up and training are complete, data collection will be performed during the project with timely entries.

Not only collection of the data is difficult, but also data interpretation carries considerable risk. Since every job is unique, current data will not match with the prospective job, so estimators should consider this as a matter of fact.

3.3.3.3 Accuracy and Validity of Data

Like all the other IT systems, ERP is based on the accuracy of the data in the system. If the ERP system is working properly, but with incorrect information, the system generates wrong information. It is a demanding process to correct the situation when the system is already in operation (Lehtinen and Pertti, 2005; cited in Salmenpaa, 2006).

As construction projects are usually fast-track processes, all users need to keep up the speed of the job. This may not be a problem for office staff to complete respective portion of the job on time; however field staff also need to provide the data in the system on time. Data latency makes the current data invalid, so users need to assure the validity of the data in the system with timely updates.

3.3.3.4 Difficulties in Implementation

A new ERP system brings many significant tools and advanced capabilities, but it demands essential changes in processes and distribution of duties in return. In order to implement and operate an ERP system successfully, **change management** issues need to be taken care of carefully.

ERP systems are very complex and complicated systems, and require high qualified users. However, construction business contains many **low-educated individuals**, and construction operations need all these low-educated and well-educated people. Therefore, ERP system needs to recognize and compensate the difference between user capabilities, so provides certain tasks and limited accessibility accordingly.

When an ERP implementation starts there will many fundamental changes in the organization. Marnewick and Labuschange (2005) mentioned the importance of speaking to the employees in their language in order to have them understand why the changes are necessary to the organization. Considering the fact that construction business manpower is very low-educated group of people, there are many difficulties in **communication** with people, especially field people, and explaining the details.

In order to minimize the time spent on training and increase the efficiency, companies should be able to handle the **employee resistance against change**. Steyn (2004) grouped the employee resistance into three as individuals who are not willing to learn, not able to learn and not knowing. Each group of employees needs different treatment in order to catch up with the new system.

Because of the project-based nature of construction business, performance of construction companies is very dependent on projects. Gencel (2003) stated that the minimum **time to see the effects of ERP in the company processes** is one year. However, one particular project may last less than 2 months, or may take longer than 10 years. Assuming that ERP implementation has started with a job will last less than a year, so the job will be done before measuring any effects of ERP. On the other hand, a case study (Gencel, 2003) in Turkish defense industry indicated the timeframe for deciding for the appropriate ERP software as three years. As this is very long time period for construction business, many parameters of the business would be changed within three years. Although there is not a certain timeframe for an ERP **selection**, none of the construction companies could spend that long time for choosing the ERP product.

Since ERP systems are based on a common platform, which implements globally standardized processes, a new ERP implementation to the organization will end all previous traditional operation processes, and also freedom to adjust **local operations**

(Nandhakumar et al., 2003). This needs to be considered through the implementation in order for the organization not to lose the advantages of local operations.

Timely completion of ERP implementation is difficult for every industry, but volatile conditions of construction business make it even more difficult. Shi and Halpin (2003) indicated that the majority of implementations could not be completed in scheduled duration and within budget.

3.4 Suitability of ERP Systems for Construction Companies

ERP systems are shedding light on future business opportunities in construction industry. The need for integration has led many companies to invest in ERP systems (Vlachopulou and Manthou, 2006). Within contractors and clients, the ERP systems lead to strength partnering, standardized reporting, common understanding of terms and functions, single data sources, wider integration opportunities, simplify contracting, subcontractor vendor interfaces, sharing contractor systems, and map work process (O'Connor and Dodd, 2000).

Current construction ERP solutions are handling many industry-specific needs of construction business. However, this cannot be said that they are complete solutions at the moment. Because of that, some construction companies integrate their own project management systems with a construction ERP system, as previously mentioned in Section 3.3.2.3. Each party of the construction industry has different needs, thus each one needs a particular solution depending on:

- Party and its role
- Company size
- Business Processes
- Project Delivery Systems
- Company assets
- In-house capabilities
- Local and international operations
- Business / project locations

- Local conditions
- Market conditions

Not all ERP systems are created equal, some do certain things better than others (Slater 1999; cited in Beekhuyzen, 2001), therefore construction parties need to figure out the best fit into their business. There are some ERP vendors providing project-oriented solutions, such as mySAP ERP (SAP, 2007d), in order to support and enhance all processes within project and plant life cycles. If more parties are using ERP systems within a project, this may be possible to transfer certain data between these systems. This may save considerable amount of time and provides accurate data on time.

There are many construction companies using ERP systems for their business in the world. However, demand on ERP systems in certain markets varies. For instance, although Netherlands and Greece may be considered as working in the same European Union market, while most of the large construction firms in the Netherlands (firms having more than 1000 employees) have implemented an ERP system into their business (Voordijk et al., 2003); Vlachopoulou and Manthou (2006) stated that there are only two large construction companies in Greece who have installed an ERP system.

On the other hand, selecting a domestic ERP product rather than a well-known worldwide ERP product makes difference in some economies. The best example is Wu and Wand's study (2003) in Taiwan. They concluded that 58% of the Top-1000 companies in Taiwan implemented domestic ERP products into their business. Although the results include all industries, not construction only, they indicate the demand on local ERP products.

The high level of inherited risks of ERP implementations resulted in the fact that only those organizations with high financial capacity and organizational maturity can manage and absorb these risks (Tatari et al., 2004).

Barthorpe et al. (2004) conducted a survey within the construction companies in UK. Results showed that majority of companies below 10 million Pound (~US$20 M) in size are not hopeful about construction ERP systems, and not willing to implement. While the companies are getting bigger in size, their expectations and willingness are

increasing as well. Their findings indicated that ERP solutions are less suitable for small and medium enterprises, and organizations with turnovers above 100 million Pound (~US$200 M) could usefully consider ERP adoption as suggested by the majority of ERP consultants.

Considering that the description of parties depends on the roles per contract, any party may change its role in a specific project. For instance, a general contractor may need to build up a new office building in a new market. In order to avoid the risks of new market, they may hire another contractor company to construct their office building. In this case general contractor becomes the owner in this project, and the other contractor company is the general contractor of this particular project. All construction parties may consider using a construction ERP system for their business. Below is the brief explanation of general perspective according to respective parties' use of an ERP system.

3.4.1 For Owners (O) and Owner's Representatives (O/R)

Owners investing in several construction projects need highly capable project control, management and execution systems. An ERP system would be a serious option for them because they will be able to see the overall status of investments, cash flow, funding replacements, completion status, as well as status of every single project. Without saying that is a perfect solution, ERP serves as a highly capable tool to provide various types of information to the owner whenever needed.

Owners can evaluate bidders through the system and award the winner accordingly. ERP system will not only be useful during the project, but also be efficient after completion of the project, especially for maintenance, warranty, and possible repair / replacement / renovation issues. Owner's representatives also can use a construction ERP system in order to handle multi projects from multi owners.

Besides, owners will be able to link the other investments or business functions to the same integrated system while utilizing an ERP product. This should be understood that, although there is no study indicating the ideal size of the owner or owner's representative to implement an ERP system, ERP can make a significant difference for the owners and owner's representatives working on large amount of projects, and

especially working in different locations, while integrating the whole business processes.

3.4.2 For Architects / Engineers (A/E)

In addition to reasons of the owners and owner's representatives to use a construction ERP system, Architect / Engineer companies may design and develop their architectural and engineering solutions using special software product, and then integrate with the ERP system. This needs to be reminded that data transfer procedure is very important as it will assign what data will be provided and how this will be provided. There are some ERP vendors providing integration solutions with specific engineering and architectural tools, such as CAD designs, however there may be an additional need of integration for another special software product.

3.4.3 For Suppliers and Vendors (S/V)

Suppliers and vendors are the most suitable parties for the use of a construction ERP system among construction business parties, since they are performing most similar job to manufacturing industry. Suppliers and vendors are the only party whose business needs may be completely ensured. Therefore, a construction ERP system can improve the business of suppliers and vendors, especially for suppliers who also manufacture the materials, considering the origination of ERP that it was created in order to control the repetitive production and increase the productivity and profit in manufacturing industry.

3.4.4 For Subcontractors (S/C) and General Contractors (G/C)

Subcontractors and general contractors have most demanding and complicated needs among construction parties. Subcontractors are generally specialized on a specific trade such as electrical, fire proofing, etc.; or a certain group of trades such as sitework and landscaping, plumbing and fire protection, MEP (Mechanical, Electrical and Plumbing), etc. In this perspective, it seems like their operations simpler than the general contractors. However, the reality is different than it seems. Since ERP is more suitable and preferable for large companies, it needs to be taken into consideration that subcontractors also employ many second tier subcontractors,

so their operations are very similar to general contractors' operations, and they may gain similar benefits by using a construction ERP system. Besides, general contractors may also work as a subcontractor for another general contractor on contractual basis.

Subcontractors and general contractors work with large number of first and second tier subcontractors within a large project. They need to use an ERP system which allows them to work with their project delivery systems, business solutions and practices (Ryoo et al., 2007). In order to simplify the language, the term "contractor" will refer to both subcontractors and general contractor in the following two paragraphs. Contractors need to control their relationships with respective subcontractors. For instance in numbers, let us assume that an owner has 10 building investments and they are all grown-up (new construction) buildings. The owner will need one representative (O/R) for each of these projects, so the owner deals with 10 parties. However, if a contractor has 10 projects, assuming that the contractor has 20 subcontractors for each project, it will deal with 200 parties for 10 projects.

On the other hand, each subcontractor performs different job than the other subcontractors within the project. Therefore, contractor's relationship with a subcontractor is different than the others. In order to handle these complex relationships, a construction ERP system, whether it may be integrated with non-ERP systems such as Prolog and Timberline or not, can be very useful, suitable and effective, considering the magnitude of construction operations.

4. CONCLUSION AND FURTHER STUDIES

ERP systems have become popular in the past decade due to its advantages in creating competitive advantage for the organizations in several sectors including the construction industry. Many researchers have studied the concept of ERP systems in various perspectives; needs, benefits, and costs of implementing ERP systems have been analyzed and proper strategies and models have been proposed considering the features of the work processes and the organization as well. However, there is limited research in the area of ERP systems in construction and there is a need for a sound and deep analysis of the properties of an ERP model to be applied to construction business that will best suit the requirements of the companies and function properly.

One of the major objectives of this thesis is to figure out the suitability of ERP system in construction business. In order to investigate the suitability of ERP systems, detailed literature review has been performed by collecting the data in different disciplines such as information systems, financials, computer science, manufacturing, automation, and construction. This broad view approach aimed to provide readers a complete set of information on ERP systems. Within this context, based on the extensive literature survey, the following features of ERP systems are discussed and main concerns for implementing ERP in organizations are highlighted:

- ERP systems allow companies to implement fully integrated systems to replace their legacy systems that are difficult to maintain because of their age, size, mission-critical status, and frequent lack of documentation.
- Implementing ERP is an extensive, lengthy, and costly process, which requires major changes to organizational, cultural, and business processes. Companies should invest in both the software itself and in related services such as consulting, training, and system integration.

- ERP systems can provide significant benefits to the organizations once they are properly selected and implemented. For a successful ERP implementation, there are several critical success factors such as; clear understanding of strategic goals, commitment by top management, excellent project management, organizational change management, a great implementation team, data accuracy, extensive education and training, focused performance measures, and multi-site issues.
- ERP systems continue to grow and are currently linked with the Web and E-commerce applications also helping the companies easily interact with other applications of different vendors. Four major trends shaping the future of ERP are improving integration and flexibility; inclusion of e-business applications; wider range of customers; and adapting to the Internet.

As far as the differences between construction and other industries are concerned, models proposed in the literature and implementation strategies should be reviewed and revised to obtain a complete solution for the project-based construction industry. The construction industry is a highly fragmented industry involving many participants including the Owner, Architect/Engineer, Owner's Representative, General Contractor, Subcontractors, Suppliers and Vendors, and District's Representative. The uniqueness of the industry prevents the direct implementation of many methods and concepts developed in the manufacturing industry. Such uniqueness leads and forces researchers to develop their own science base, principles, and application procedures for the sustainability of this major industry. In the context of this research study, firstly the fragmented nature of construction business has been explained, then ERP systems in construction business has been mentioned identifying their objectives, benefits, risks, conceptual models and current ERP systems in use.

The following issues are discussed for a successful construction ERP system if certain benefits are to be derived by the construction industry:

- There is a common terminological confusion for the terms "ERP system" and "construction ERP system". Although some researchers recognize construction ERP systems as separate and different than ERP systems, this study describes construction ERP system as an ERP system, which provides

comprehensive solutions to construction business' industry-specific problems and needs.

- The goal of ERP in construction is to support one time entry of information at the point where it is created and to make it available to all the participants within the organization.
- Since existing ERP systems are primarily developed for the manufacturing industry, they can hardly meet the needs of the construction industry. However, employing some necessary steps, construction industry can also benefit from the advantages created by ERP systems.
- Main benefits of a construction ERP application include information sharing, improved transparency of management responsibilities, improved management efficiency, integrated working environment, automation of processes, world-wide business globalization, balanced manpower, and ability to control practices through the project life cycle.
- On the other hand, application of ERP in construction may arise some risks while handling seasonal workload fluctuation and unstable lower-than-cost bids, functional misfits, ERP's negative impact on the work practices and culture, and high implementation cost and timeframe for the return on investment. In this respect, it should be kept in mind that every improper action creates new risk of failure, so any mistake through the life-time of a construction ERP system will be a threat as ERP is based on the accuracy of data just like every other computer-based information system.

It is concluded that there is still not a genuine ERP system which is able to cover all of unique needs of construction business satisfactorily.

- There are many limited-scope construction ERP applications as available software packages allow companies and owners to implement on a certain part of their business. Available ERP products include SAP R/3, mySAP EC&O, EasyBuild, CMiC, IFS, and OPTICON.
- Most of construction ERP applications are related to non-construction part of the business implementations such as financials, accounting, and human resources.

- Procurement process for construction industry is the most similar process with the same process of manufacturing industry among all processes. Since many intermediate steps of the procedure overlap, material management applications are the most common “true” construction ERP application examples considering their practical applicability and transmission convenience from manufacturing business language to construction business language.
- Based on the analysis of current applications, one of the most remarkable conclusions is that it is not possible to make generalizations based on the available case studies and success stories of the companies as they have considerable differences in details. ERP implementation is extremely comprehensive application and depends on numerous factors, so typological data is needed in order for researchers to reach generalized consequences, and this will take years for the market to produce that kind of data by business applications.

In implementing construction ERP systems, there are several difficulties to be overcome by the companies so that planned objectives and targets are met. This study identifies the difficulties that prospective ERP users in construction business will face with. Those difficulties are categorized into four as following: difficulties in construction ERP studies, difficulties in using current ERP products, difficulties in information technology (IT) applications, and difficulties in implementation.

- Since there are many different categorizations for construction ERP products, vendors, clients, industries, almost none of the findings are completely validated. Therefore, diversity of the affecting factors should be deliberately reviewed according to the particular purpose of the research. The wide scope of ERP and the complexity of the system force researchers to narrow down into smaller pieces of the subject. Also vast number of participants and various different types of implementations increase the diversity of the case conditions, so researchers need to set the conditions very carefully as field studies can only be conducted once. The major problem indeed is that a science base of ERP technology has not developed yet and that the ensemble of separated functional systems is untested.

- Current ERP Products such are handling many functions of construction business. Most of ERP products provide certain level of satisfaction on back-office functions such as order management, financial management, warehousing, distribution, quality control, asset management, and human resources, as they are basic elements of a business and are more or less same for every industry. Divergent part of construction business from the other industries is front-office functions such as site management, project management, estimating, bidding, and scheduling. It is concluded that, based on the previous studies, most of the deficient functions of current ERP systems are front-office functions.
- The fragmentation of construction business has also led to the fragmentation in type, quality, and amount of data and information generated throughout a project's life cycle. Like all the other IT systems, ERP is based on the accuracy of the data in the system. Data latency makes the current data invalid, so users need to assure the validity of the data in the system with timely updates.
- Difficulties in implementation, on the other hand, involves issues such as necessity for change management and for highly educated individuals, effective communication with people, coping with the employee resistance against change, time to see the effects of ERP in the company processes, selecting a proper system, freedom to adjust local operations, and timely completion of ERP implementation.

Considering the activities carried out in a construction project, some determinations and recommendations are provided in order to handle some difficulties in using current ERP products, in terms of scheduling, accounting, and integration issues.

- *Construction Scheduling:* A construction project involves scheduling of construction activities, manpower scheduling, and material and equipment scheduling. Main problems in this area is about the understanding of scheduling, and working with static scheduling tools. Therefore, construction scheduling needs flexible tools in order to keep the project under control against changes, and also needs to see the time and cost effects of changes. This is also tremendously necessary to see the status of the project on a cost

and resource loaded schedule in order to project timeliness of the project, as well as the cost completion. This should be emphasized that financial status usually does not explain or point out any ongoing problems of the project, so this is insufficient information on project management side of the business. As a result, a construction ERP product should utilize high-capability construction scheduling module, which allows users to make any changes on the existing schedule, follow the impacts, and figure out cost related changes accordingly. This module also needs to be in relation with project management and accounting modules so respective parties may proceed with their part of the process.

- *Construction Accounting:* Construction accounting operates some regular tasks different than the other industries, also has some additional procedures. Construction accounting operations contain some industry-specific processes such as retainage accounting, pay-when-paid policy, subcontractor compliance and certification, productivity-based forecasting, job cost reports, change orders, rework and backcharges, and accounting standards.
- *Integration with Non-ERP Systems:* Current construction ERP products may not exactly fit in the needs of a construction company. It is possible to ask vendors to customize the product accordingly; however it is limited to vendor's capability and capacity to accommodate all requests. In this case, construction companies may need to utilize supporting software products in integration with their ERP system. However, these systems can transfer and interchange data in varying degrees. Validation routines of the bridging must be updated and data exchange routines must be retested. This may cause some difficulties or inconvenience in further times while maintaining integrated systems.

Considering the parties involved in a construction project, each participant's role and benefit should be clearly distinguished and a conceptual model should be proposed accordingly. All participants may consider using a construction ERP system for their business. Each party has different needs, thus each one needs a particular solution depending on party and its role, company size, business processes, project delivery systems, company assets, in-house capabilities, local and international operations, business/project locations, local conditions, and market conditions. Following are

some recommendations for each participant:

- *For Owners (O) and Owner's Representatives (O/R):* Owners investing in several construction projects need highly capable project control, management and execution systems. Owners can evaluate bidders through the system and award the winner accordingly. Although ERP systems cannot respond to all needs of construction business yet, an ERP system is a serious option for the owners and owner's representatives. ERP system will not only be useful during the project, but also be efficient after completion of the project, especially for maintenance, warranty, and possible repair / replacement / renovation issues. Owner's representatives also can use a construction ERP system in order to handle multi projects from multi owners. Besides, owners will be able to link the other investments or business functions to the same integrated system while utilizing an ERP product.

- *For Architect/Engineer (A/E):* Architect / Engineer companies may design and develop their architectural and engineering solutions using special software product, and then integrate with the ERP system. Although there are some smooth integration examples provided by ERP vendors, comprehensive solutions are still needed.

- *For Suppliers and Vendors (S/V):* Suppliers and vendors are the most suitable parties for the use of a construction ERP system among construction business parties. Suppliers and vendors are the only party whose business needs may be completely ensured, especially for suppliers who also manufacture the materials.

- *For Subcontractors (S/C) and General Contractors (G/C):* Subcontractors and general contractors have most demanding and complicated needs among construction parties. Subcontractors and general contractors work with large number of first and second tier subcontractors within a large project. Contractors need to control their relationships with respective subcontractors. On the other hand, each subcontractor performs different job than the other subcontractors within the project. Therefore, contractor's relationship with a particular subcontractor is different than the others. In order to handle these complex relationships, a construction ERP system, whether it may be

integrated with non-ERP systems such as Prolog and Timberline or not, is very useful, suitable, and effective, considering the magnitude of construction operations.

The need for integration has led many companies to invest in ERP systems. Not all ERP systems are created equal, some do certain things better than others, therefore construction parties need to figure out the best fit into their business. While the companies are getting bigger in size, their expectations and willingness are increasing as well. ERP solutions are less suitable for small and medium enterprises; organizations with turnovers above USD 200 M could usefully consider ERP adoption as suggested by the majority of ERP consultants. The high level of inherited risks of ERP implementations result in the fact that only those organizations with high financial capacity and organizational maturity can manage and absorb these risks. If more parties are using ERP systems within a project, this may be possible to transfer certain data between these systems. This may save considerable amount of time and provides accurate data on time. On the other hand, selecting a domestic ERP product rather than a well-known worldwide ERP product makes difference in some economies. It will be consecutive result of the construction industry that construction ERP systems will spread all over and become more popular.

Number of ERP studies in construction has been increasing, and most of the current studies have been done within last 4 years such as Ahmed et. al (2003), Barthorpe et. al. (2004), Ifinedo and Nahar (2006), Rawlins (2004), Ryoo et. al. (2007), Shi and Halpin (2003), Tatari et. al. (2007), Vlachopoulou and Manthou (2006), and Voordjik et. al. (2003). That shows that the interest of researchers on the ERP systems in construction is increasing, and that also proves that attention of the construction business participants on ERP in construction is increasing as well. In parallel, ERP vendors are improving their products in order to satisfy the needs of the sector. Since ERP is an extremely wide subject, the ERP vendors must work with both researchers studying on ERP in construction and the professionals in the construction industry in order to phase and plan the development of better solutions, and, as a result, to obtain more capable and competitive products in the world market.

In the future, researchers may investigate the following areas in order to contribute

the ERP studies in construction and provide better solution to the construction industry participants:

Since many activities of construction operations have non-standard characteristics, researchers may focus on the methodologies how ERP systems may store the experience and lessons learnt, and also ways for integration of the organizational knowledge with ERP system processes in construction may be investigated. Compatibility of object oriented models and unstructured databases with ERP processes may be studied in the future.

Within vast amount of ERP modules, construction scheduling module should be deliberately studied. Available solutions need to be improved. All construction scheduling activities, including material, manpower, equipment and construction activity scheduling, need to be communicating with other respective modules such as accounting, job cost reports, change order management, project management.

Also, better integration applications of ERP systems with non-ERP systems need to be developed in order to utilize the current highly capable non-ERP systems in the construction business.

Another significant study may be in regards to transition from existing legacy systems to ERP systems in construction. Factors determining the timeframe for implementation in construction business and problems during the transition may be examined. Specifically, preparation of the convenient business environment to implement a new ERP in construction, handling difficulties with ongoing projects (projects on hand), bidding strategies within the period, phasing the implementation to minimize unwanted aspects on business may be studied.

Besides, case studies on ERP applications in construction front-office functions would be widely beneficial in order to gain the data for further data classifications and generalizations. Inevitably, these case study can only be done with strong collaboration of the companies in the field and researchers at universities and institutions.

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RESUME

Tugcag Arda Cotuk was born in 1979 in Izmir, Turkey. While studying in Izmir Turk College – Science High School, he was chosen as a member of the TUBITAK (The Scientific and Technical Research Council of Turkey) Olympic Team of Mathematics, in 1995. He has earned his Bachelor of Science in Architecture at Istanbul Technical University in 2003, being honored as the first student in the Architecture Faculty completing undergraduate studies in three years. He had his Master of Construction Engineering and Managment degree at Illinois Institute of Technology in 2005, and will be completing his Construction and Project Management Master's Program at Istanbul Technical University in June 2007 and will earn his MSc. degree. He has been working for G.F. Structures Corporation in Chicago since 2005 as Assistant Project Manager, and is currently enrolled to another master's program at Illinois Institute of Technology, which is Master of Architectural Engineering.